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Systems Analysis Study of Solid Waste Collection Management. Volume II. Reports on Simulation Tasks

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1977

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SYSTEMS ANALYSIS STUDY
OF SOLID WASTE COLLECTION MANAGEMENT

Volume II

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Volume I reports on network coding,
network selection, and information system tasks.

Volume II contains simulation tasks.

U.S. ENVIRONMENTAL PROTECTION AGENCY

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The objective of this study was to demonstrate the use of automatic techniques in supporting solid waste management. Automation techniques were demonstrated in two major areas:

-Resource scheduling, measuring, and reporting for management (Volume I)
-Operational simulation for evaluation of management strategies and options (Volume II)

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An environmental protection publication (SW-150c.2) in the solid waste management series.

PREFACE

A Solid Waste Collection Study was initiated in Wichita Falls, Texas, in October, 1972. The objective of the project was to demonstrate the use of automation techniques in supporting solid waste management. Automation techniques were demonstrated in two major areas:

- Resource scheduling, measuring, and reporting for management control
- Operational simulation for evaluation of management strategies and options

The management control area encompassed three substantial tasks. They were:

- The development and demonstration of automated techniques for coding a solid waste collection network.
- The development and demonstration of automated techniques for selecting efficient collection routes through a network and optimizing resource assignments to collection routes.
- The development and implementation of an automated solid waste management information system.

The simulation and strategy evaluation area encompassed two substantial tasks. They were:

- (1) The development of a simulation model that will represent any of several solid waste collection environments. ; and
- (2) The demonstration of the model as a tool for evaluating management strategies and for developing collection system optimization recommendations.

The work effort and results of these five major project tasks are reported in the two volumes of this project final report. The network coding, network selection, and information system tasks are included in Volume I. The simulation tasks are in Volume II.

These

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CHAPTER I

INTRODUCTION

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INTRODUCTION

A simulation model of solid waste collection systems and demonstration of its use as a tool for the planning and management of these systems are presented in this volume. The simulation model is designed to enable quantitative evaluation of several types of residential and commercial collection systems. Specifically, the model can predict the performance of the following types of systems:

- Residential collection systems of the container-train, packer-truck, alley/street-container, or mechanical-bag-retriever type

- Commercial collection systems of the container-transfer-vehicle or packer-truck type

In addition, any system that has components and an operation similar to any of these systems can also be simulated by the model.

The model can simulate the operation of these systems under a wide variety of collection conditions that impact system performance. Thus, the model can be used to provide a rational basis for decision-making relative to many aspects of planning and management of solid waste collection systems. Included are decisions concerned with selecting collection vehicles and crew sizes; routing and scheduling collection vehicles; establishing collection policies regarding collection frequency, point of collection (e.g., curb pickup or carry-out service), and type of storage container(e.g., cans or bags); specifying collection vehicle reliability and maintainability standards; and locating disposal sites and transfer stations.

The model is a computer simulation model that can be used to provide either a deterministic or a stochastic representation of solid waste collection. It is composed of the following three program modules written for an IBM System/360 computer:

- Input Program Module--A program written in COBOL that edits the input data deck and generates a tape to be input to the Simulation Program Module.

- Simulation Program Module--A program written in FORTRAN IV that calculates the performance of the system described on the input tape and generates a summary of the performance on a tape to be input to the Output Program Module.

- Output Program Module--A program written in COBOL that prints several reports from the performance summary tape generated by the Simulation Program Module.

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A schematic which illustrates the structure of the simulation model in terms of these modules is shown in Figure 1.

A description of the various components of the simulation model is presented in the following chapters:

- Chapter III - Input Program Module
- Chapter IV - Simulation Program Module
- Chapter V - Main Program
- Chapter VI - Activity Subprograms
- Chapter VII - Utility Subprograms
- Chapter VIII - Output Program Module

The collection systems and conditions that can be simulated by the model are described in Chapter II. And, the demonstration and utilization of the model as a tool for evaluating solid waste collection planning/management alternatives are discussed in Chapter IX.

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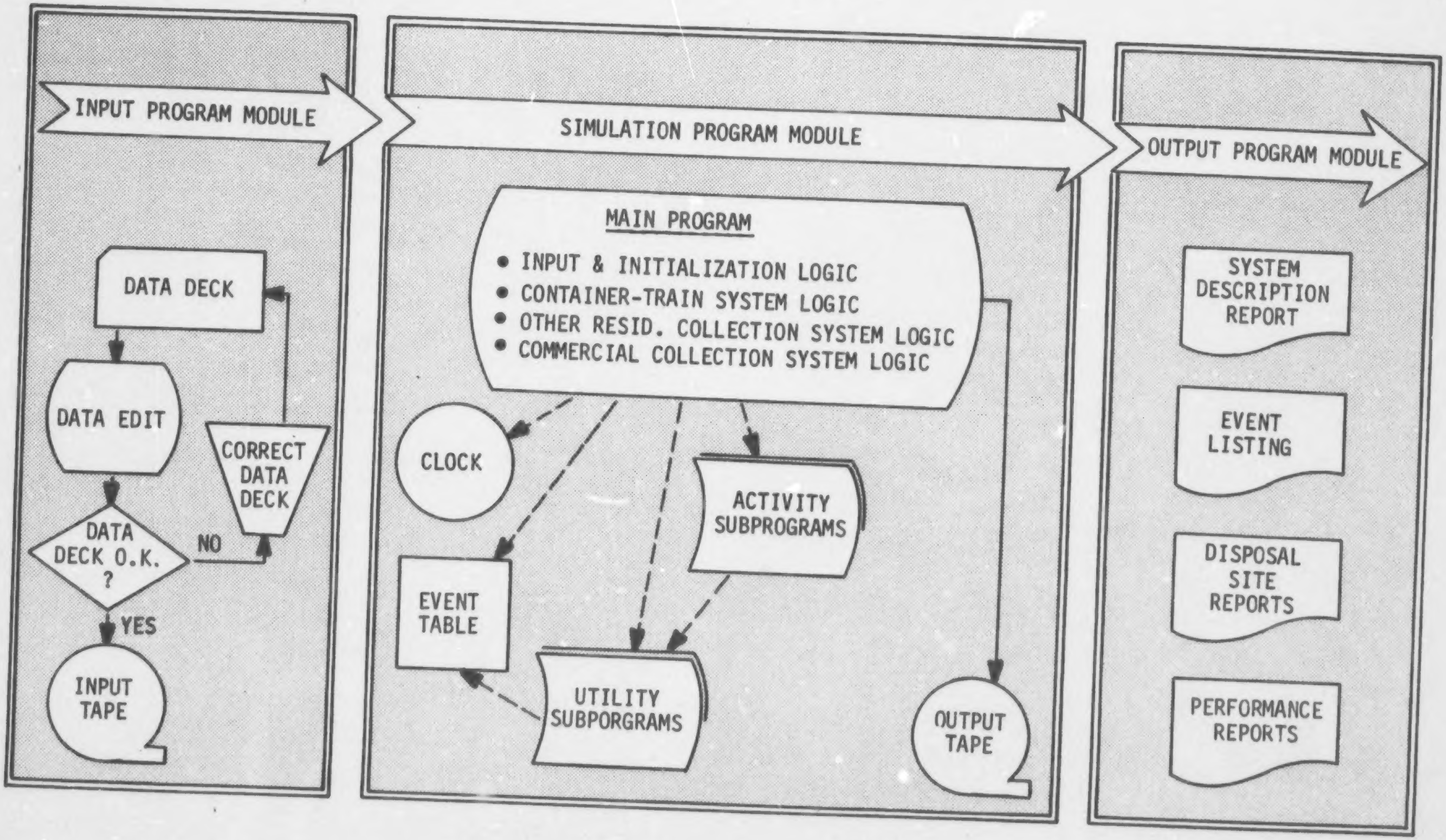
INPUT PROGRAM MODULE
DATA DECK
DATA EDIT
DATA DECK O.K. ?
NO
CORRECT DATA DECK
YES
INPUT TAPE
SIMULATION PROGRAM MODULE
MAIN PROGRAM
• INPUT & INITIALIZATION LOGIC
• CONTAINER-TRAIN SYSTEM LOGIC
• OTHER RESID. COLLECTION SYSTEM LOGIC
• COMMERCIAL COLLECTION SYSTEM LOGIC
CLOCK
EVENT TABLE
ACTIVITY SUBPROGRAMS
UTILITY SUBPORGRAMS
OUTPUT TAPE
OUTPUT PROGRAM MODULE
SYSTEM DESCRIPTION REPORT
EVENT LISTING
DISPOSAL SITE REPORTS
PERFORMANCE REPORTS

SCHEMATIC OF SIMULATION MODEL

Figure 1

CHAPTER II

DESCRIPTION OF SOLID WASTE COLLECTION SYSTEMS

DESCRIPTION OF SOLID WASTE COLLECTION SYSTEMS

RESIDENTIAL COLLECTION SYSTEMS

The model is designed to simulate the performance of the following types of residential collection systems:

- Container-train systems
- Packer-truck systems
- Alley/street-container systems
- Mechanical-bag-retriever systems

However, any residential collection system that has components and an operation similar to one of these systems can be simulated by the model. The components and operations of these systems, which provided the basis for the formulation of the model, are described in this section.

Container-Train System

The container-train system is a type of residential collection system that is currently being used in Wichita Falls, Texas.

Components. The basic components of a container-train system are the following:

- Fixed Container--A fixed container is a container which is stationed at a commercial collection unit to collect solid waste from the commercial collection unit. The solid waste which it collects is dumped from it and hauled to a disposal site by a container transfer vehicle. A fixed container usually has a capacity of 3, 4, or 8 cubic yards. One with a capacity of 8 cubic yards is shown in Figure 2.
- Train--A train is a collection vehicle which collects solid waste from residential collection units. The solid waste which it collects is dumped from it and hauled to a disposal site by a container transfer vehicle. It consists of a pickup pulling a number of container trailers as shown in Figure 3. Usually, the pickup has a 3-cubic-yard container in its bed and pulls three, 5-cubic-yard, container trailers. Normally, the crew of a train is composed of a driver and two or more loaders.
- Container Transfer Vehicle--A container transfer vehicle is a collection vehicle which collects solid waste from trains and fixed containers and transports it to a disposal site. It is a truck which is equipped with a system for lifting train and fixed containers and dumping the solid waste from them into a large covered container on its bed. (A container transfer vehicle is shown dumping a container trailer in Figure 4.) A container transfer vehicle usually has a capacity of 20 cubic yards or more, and it is equipped with a mechanism for compacting the solid waste. Normally, the crew of a container transfer vehicle consists of only a driver, but in some cases, it may also include an assistant.

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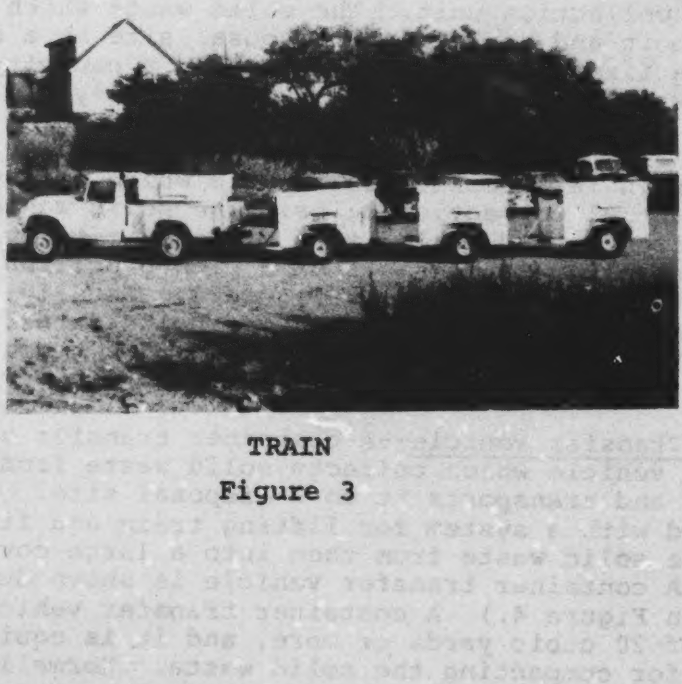
FIXED CONTAINER

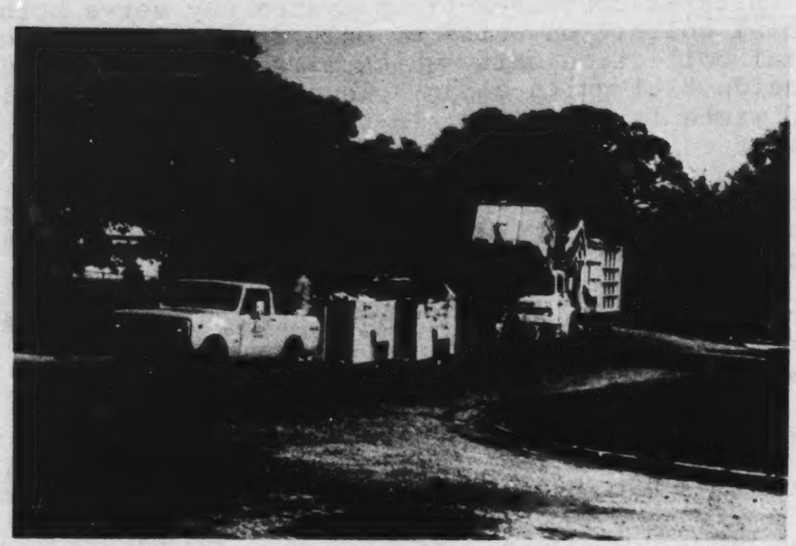
Figure 2



TRAIN

Figure 3

(14)



CONTAINER TRANSFER VEHICLE

Figure 4

- Headquarters--A headquarters is a location where collection vehicles are stationed. It is the location from which collection vehicles depart to begin their collection day and to which they return to end it.

- Disposal Site--A disposal site is a location to which the solid waste collected is hauled by a container transfer vehicle for disposal. It may be a transfer station, sanitary landfill, incinerator, or other type of disposal facility.

- Collection Units--A container-train system may serve both residential and commercial collection units or only residential collection units. A residential collection unit, which is served by a train, is the group of residential units along a length of street or alley from which solid waste is collected. A train may provide the following three types of collection service:

  - Alley pickup - train travels along an alley behind the residential units and collects solid waste from trash cans or bags placed in the alley.

  - Curb pickup - train travels along a street in front of the residential units and collects solid waste from trash cans or bags placed at the curb.

  - Carry-out - train travels along a street or alley and the collection workers walk to the residential units, place the solid waste from trash cans or bags into a large tub, and carry it back to the train.

  A commercial collection unit, which is served by a container transfer vehicle, is one or more fixed containers stationed at the site of a non-residential activity.

Operation. The basic operational unit of a container-train system is the convoy. A convoy usually consists of a container transfer vehicle and four trains which it is assigned to serve. The trains are assigned specific collection routes in residential areas. As a train travels along its residential collection route, solid waste from the residential units is dumped by the crew into it containers. When the train's containers are filled or its route is completed, it is dumped by the container transfer vehicle. In addition to serving the trains in its convoy, the container transfer vehicle may also be assigned a commercial collection route, which is a set of specific commercial collection units that it is to serve. Thus, depending on conditions, a container transfer vehicle may alternately dump trains and fixed containters. When the container transfer vehicle is full or its collection activities are completed, it dumps the solid waste it has collected at a disposal site. The fundamental operational sequence of a train and a container transfer vehicle are shown in Figure 5 and 6, respectively.

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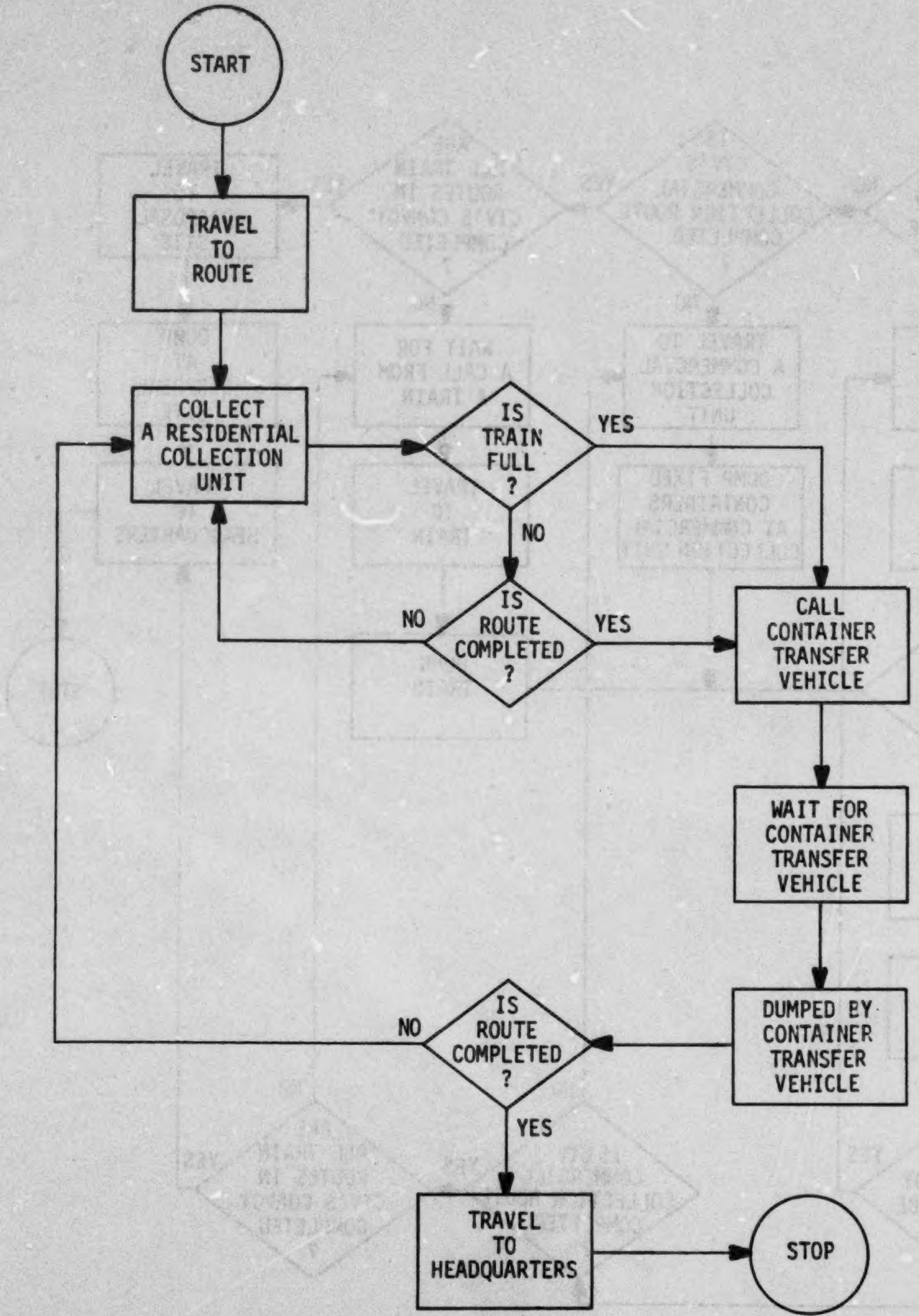
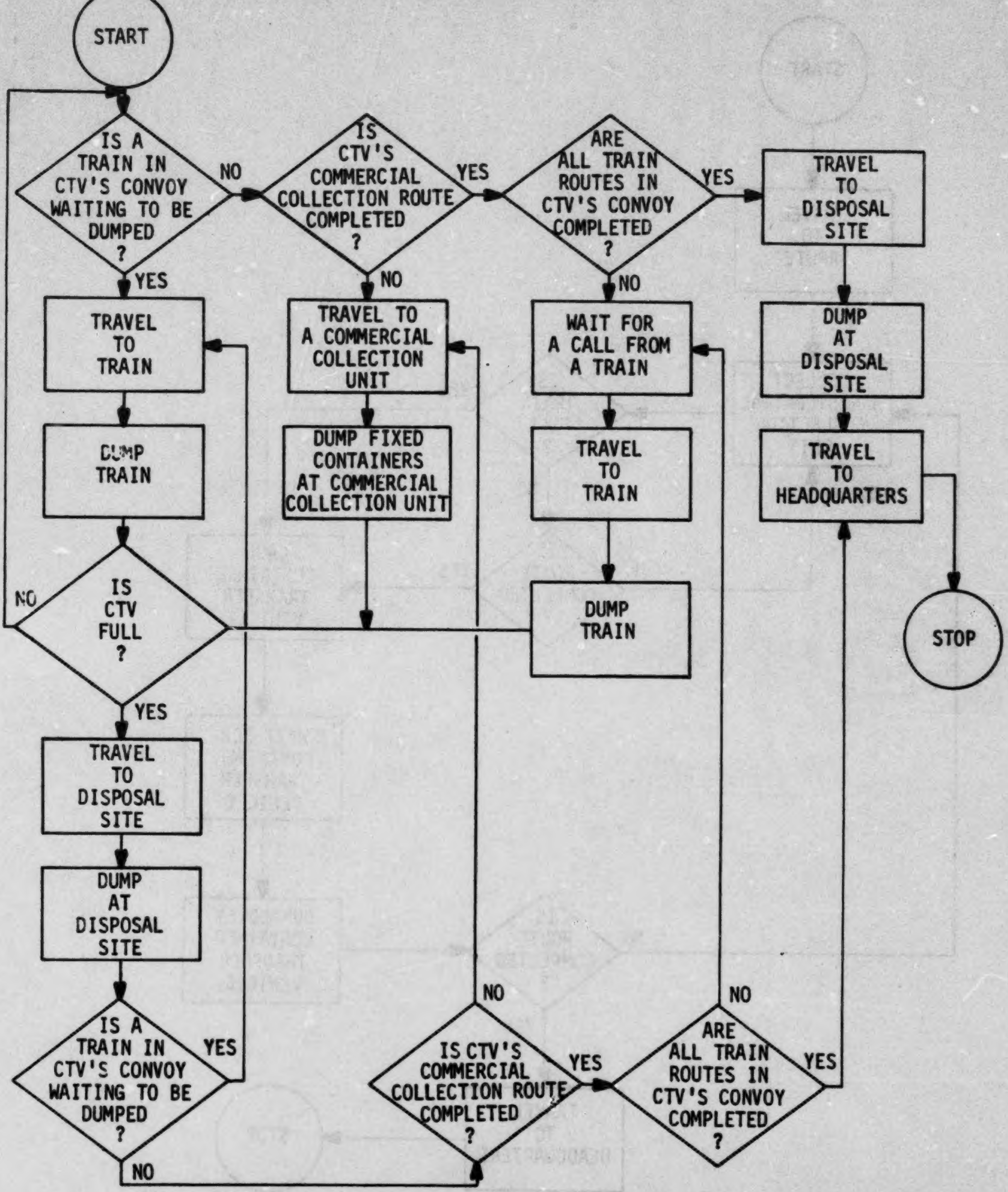

START
TRAVEL TO ROUTE
COLLECT A RESIDENTIAL COLLECTION UNIT
IS TRAIN FULL ?
YES
NO
IS ROUTE COMPLETED ?
NO
YES
CALL CONTAINER TRANSFER VEHICLE
WAIT FOR CONTAINER TRANSFER VEHICLE
DUMPED BY CONTAINER TRANSFER VEHICLE
IS ROUTE COMPLETED ?
NO
YES
TRAVEL TO HEADQUARTERS
STOP

OPERATIONAL SEQUENCE OF A TRAIN OF A CONTAINER-TRAIN SYSTEM
Figure 5

(12)



START
IS A TRAIN IN CTV'S CONVOY WAITING TO BE DUMPED ?
NO
YES
IS CTV'S COMMERCIAL COLLECTION ROUTE COMPLETED ?
YES
NO
ARE ALL TRAIN ROUTES IN CTV'S CONVOY COMPLETED ?
YES
NO
TRAVEL TO DISPOSAL SITE
TRAVEL TO TRAIN
TRAVEL TO A COMMERCIAL COLLECTION UNIT
WAIT FOR A CALL FROM A TRAIN
DUMP AT DISPOSAL SITE
DUMP TRAIN
DUMP FIXED CONTAINERS AT COMMERCIAL COLLECTION UNIT
TRAVEL TO TRAIN
TRAVEL TO HEADQUARTERS
NO
IS CTV FULL ?
DUMP TRAIN
STOP
YES
TRAVEL TO DISPOSAL SITE
DUMP AT DISPOSAL SITE
NO
NO
IS A TRAIN IN CTV'S CONVOY WAITING TO BE DUMPED ?
YES
IS CTV'S COMMERCIAL COLLECTION ROUTE COMPLETED ?
YES
ARE ALL TRAIN ROUTES IN CTV'S CONVOY COMPLETED ?
YES
NO

OPERATIONAL SEQUENCE OF A CONTAINER TRANSFER VEHICLE (CTV)
OF A CONTAINER-TRAIN SYSTEM

Figure 6

Other Residential Collection Systems

The other types of residential collection systems which the model is designed to simulate have essentially the same components and operation.

Components. The basic components of the other types of residential collection systems are the following:

- Collection Vehicle--A collection vehicle collects solid waste from residential collection units and hauls it to a disposal site. Depending on the type of residential collection system, the collection vehicle is one of the following:

    - Packer truck
    - Alley/street-container collection vehicle
    - Mechanical bag retriever

  (Photographs of these types of collection vehicles are shown in Figures 7, 8, and 9.) These collection vehicles usually have capacities of 16 to 32 cubic yards, and are equipped with a mechanism for compacting the solid waste. Normally, the crew of a packer truck consists of a driver and one or more loaders, whereas the crews of the other types of collection vehicles usually include only a driver. The collection vehicle of an alley/street-container system is also equipped with a system for dumping alley/street containers, and the mechanical bag retriever is equipped with a system for picking up bags.

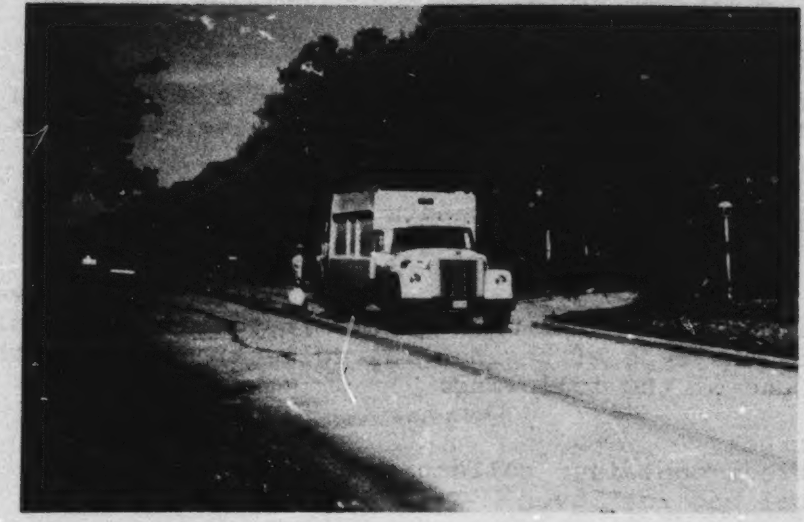
- Headquarters--A headquarters is a location where collection vehicles are stationed. It is the location from which collection vehicles depart to begin their collection day and to which they return to end it.

- Disposal Site--A disposal site is a location to which a collection vehicle hauls the solid waste it collects for disposal. As in the case of a container-train system, a disposal site may be a transfer station, sanitary landfill, incinerator, or other type of disposal facility.

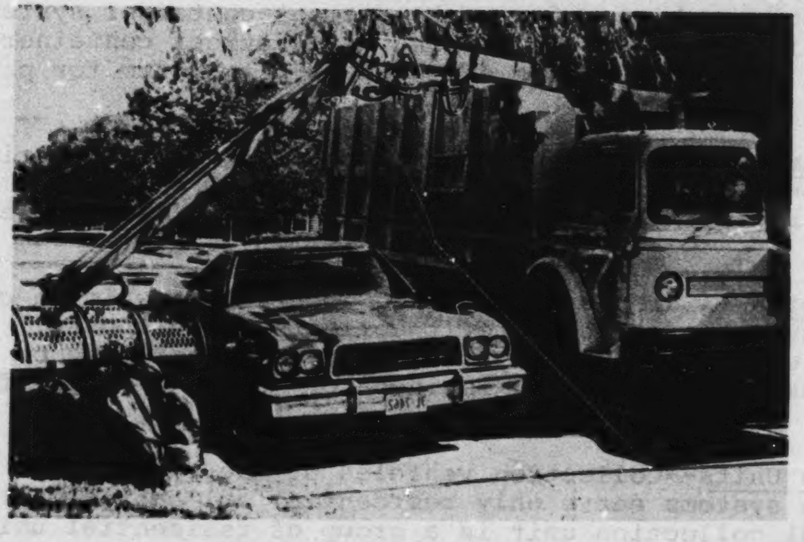
- Collection Units--Collection vehicles of the other types of residential collection systems serve only residential collection units. A residential collection unit is a group of residential units along a length of street or alley from which solid waste is collected.

  A packer truck may provide the following three types of collection service:

    - Alley pickup - packer truck travels along an alley behind the residential units and collects solid waste from trash cans or bags placed in the alley.

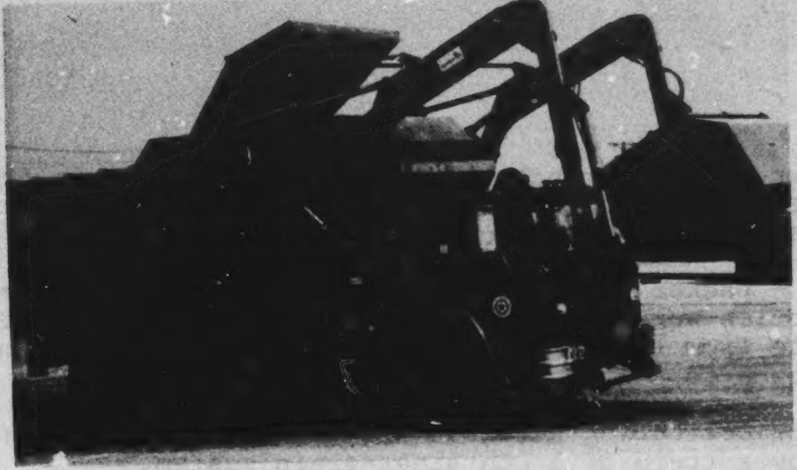


PACKER TRUCK
Figure 7

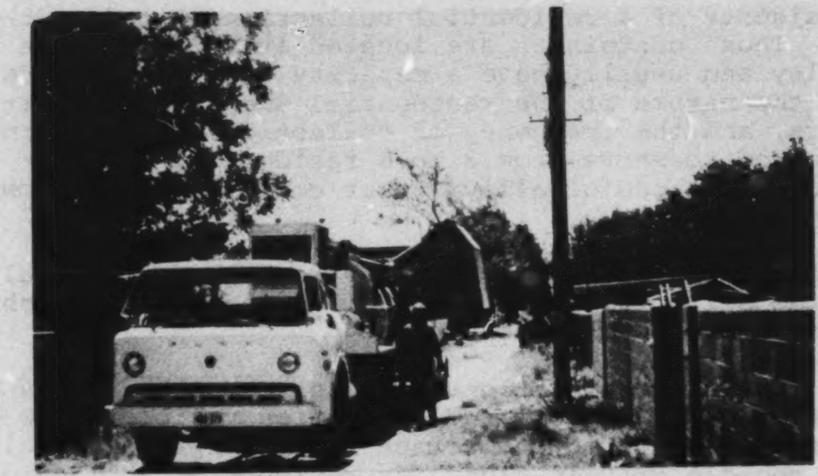


MECHANICAL BAG RETRIEVER
Figure 8

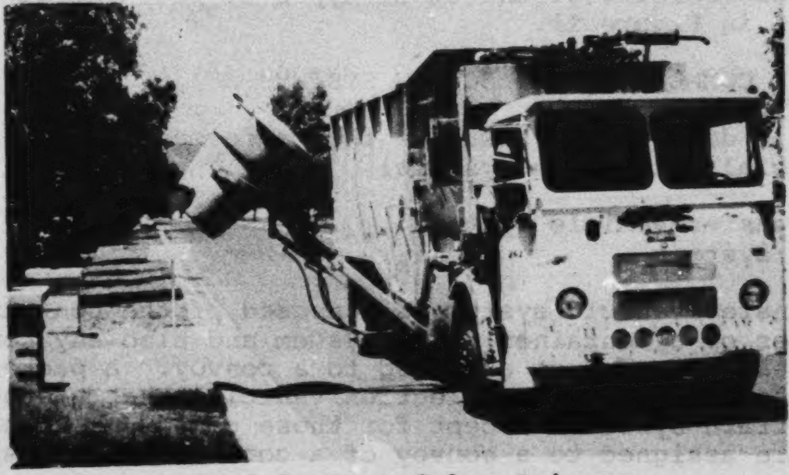
20



Type Used In Abilene, Texas



Type Used In Odessa, Texas



Type Used In Scotsdale, Arizona

ALLEY/STREET-CONTAINER COLLECTION VEHICLES
Figure 9

- Curb pickup - packer truck travels along a street in front of the residential units and collects solid waste from trash cans or bags placed at the curb.

- Carry-out - packer truck travels along a street or alley and the collection workers walk to the residential units, place the solid waste from trash cans or bags into a large tub, and carry it back to the packer truck.

These types of collection services are the same as those that may be provided by a train of a container-train system.

In the case of an alley/street-container system, the collection vehicle collects solid waste from alley/street containers, into which the residents of a residential collection unit dump their solid waste. These containers are located at the curb of a street or in the alley and usually have a capacity of 3 cubic yards. Depending on the nature of the residential area, the capacity of the containers, and the frequency of collection, one container is normally intended to serve from 3 to 5 residential units. Photographs of two types of alley/street containers are shown in Figure 10.

A mechanical bag retriever may provide both curb and alley pickup, but the solid waste must be in bags and not in trash cans. It does not provide a carry-out service.

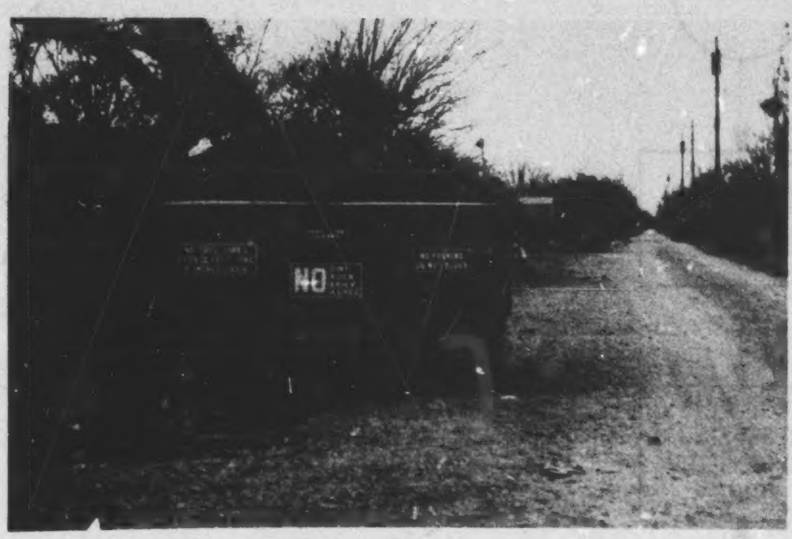
Operation. The basic operational unit of the other types of residential collection systems is the collection vehicle. The collection vehicles are assigned specific collection routes in residential areas. As a collection vehicle travels along its residential collection route, it collects solid waste from the residential collection units. When it is full or its route is completed, a collection vehicle dumps the solid waste at a disposal site. The fundamental operational sequence of the collection vehicles of the other types of residential collection systems is shown in Figure 11.

COMMERCIAL COLLECTION SYSTEMS

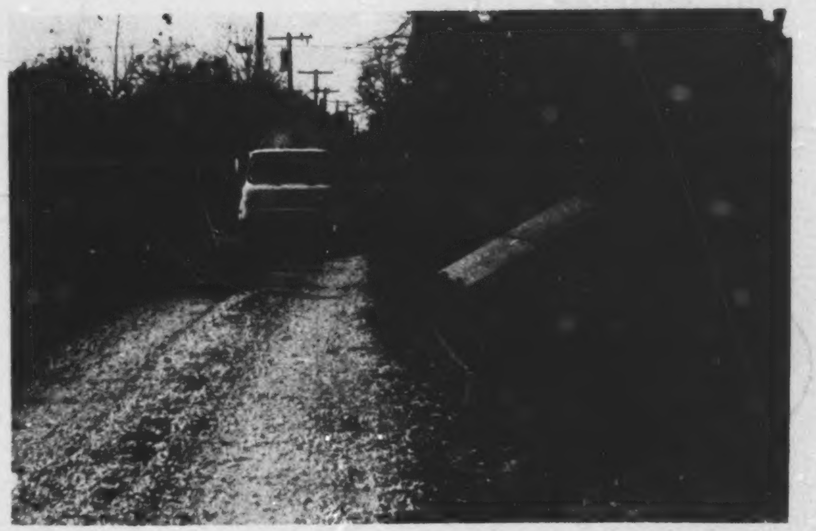
The model is designed to simulate the performance of the following types of commercial collection systems:

- Container-transfer-vehicle systems
- Packer-truck systems

A container-transfer-vehicle system is composed of the container transfer vehicles of a container-train system and also any container transfer vehicles that are not assigned to a convoy. A packer-truck system is composed entirely of collection vehicles that are not a part of a container-train system. Except for those container transfer vehicles that are assigned to a convoy of a container-train system,

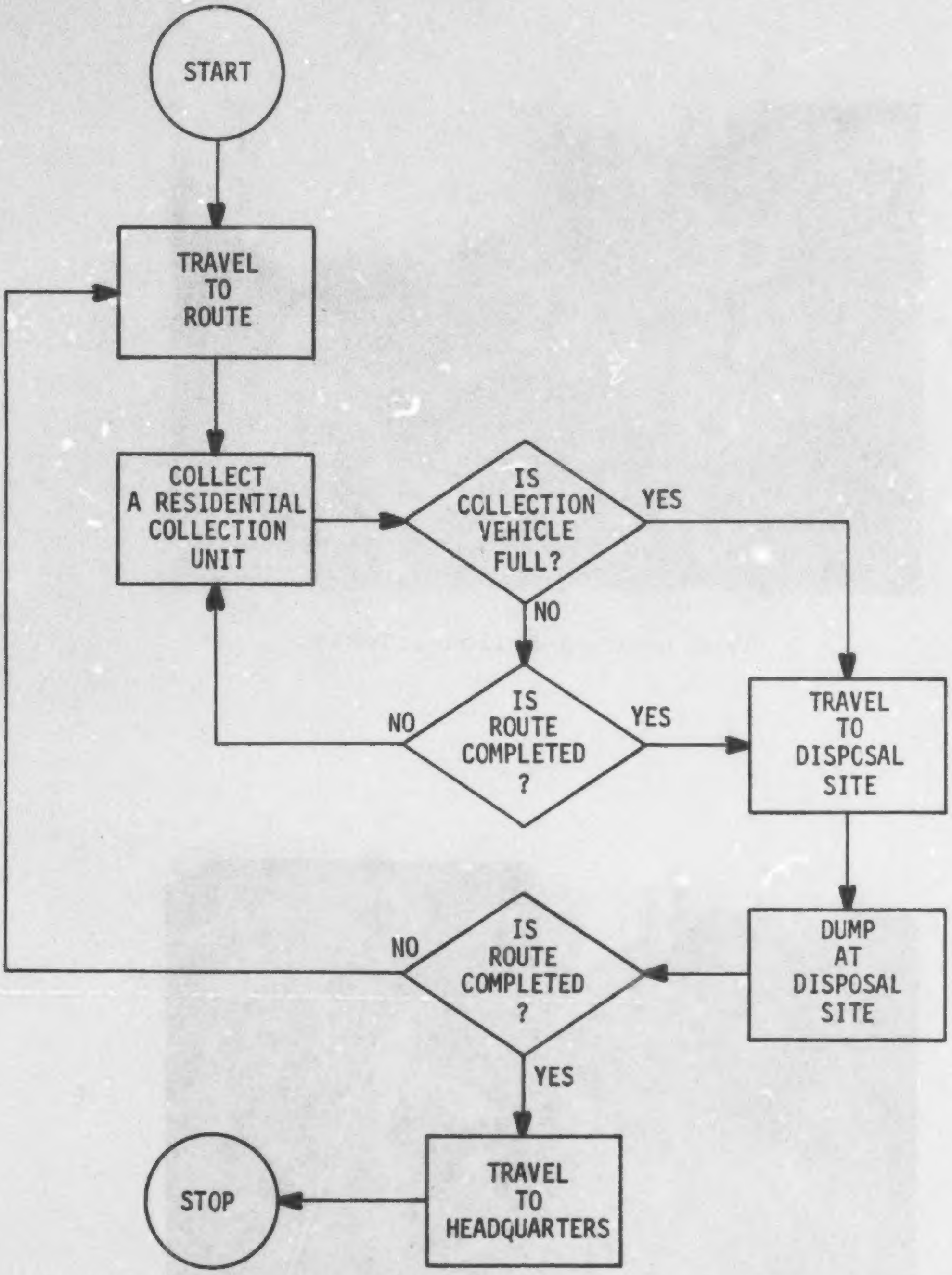


Type Used In Abilene, Texas



Type Used In Odessa, Texas

ALLEY/STREET CONTAINERS
Figure 10


START
TRAVEL TO ROUTE
COLLECT A RESIDENTIAL COLLECTION UNIT
IS COLLECTION VEHICLE FULL?
YES
NO
IS ROUTE COMPLETED ?
NO
YES
TRAVEL TO DISPOSAL SITE
DUMP AT DISPOSAL SITE
IS ROUTE COMPLETED ?
NO
YES
TRAVEL TO HEADQUARTERS
STOP

OPERATIONAL SEQUENCE OF A COLLECTION VEHICLE
OF A PACKER-TRUCK, ALLEY/STREET - CONTAINER, OR
MECHANICAL-BAG-RETRIEVER SYSTEM

Figure 11

the components and operation of these two types of commercial collection systems are essentially the same. Any other type of commercial collection system that has similar components and operation can be simulated by the model. Those container transfer vehicles that are part of a container-train system operate as described in the discussion of the operation of a container-train system and as illustrated by the operational sequence shown in Figure 5. Therefore, they are not included in the following discussion of the components and operation of commercial collection systems.

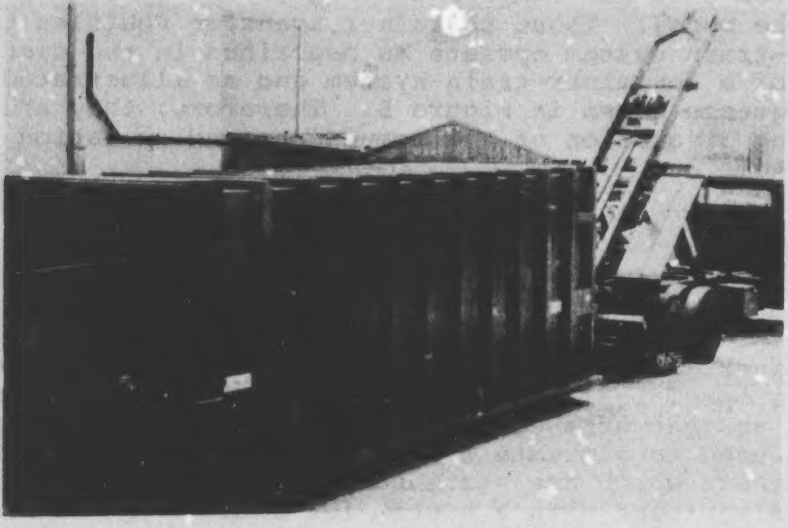
Components

The basic components of the commercial collection systems are the following:

- Fixed Container--For the types of commercial collection systems that the model is specifically designed to simulate, a fixed container is the same as that of a container-train system. However, the model can also be used to simulate a commercial collection system that has fixed containers which are stationary compactors. A stationary compactor is equipped with a system for compacting the solid waste, and it normally has a capacity of 20 cubic yards. A photograph of a stationary compactor is shown in Figure 12.
- Collection Vehicle--For the types of commercial collection systems that the model is specifically designed to simulate, a collection vehicle is similar to the container transfer vehicle of a container-train system or the collection vehicle of an alley/street-container system which are shown in Figures 4 and 8, respectively. The collection vehicle of a stationary-compactor system, which can also be simulated by the model, is a semi-trailer truck equipped with a system for loading stationary compactors on to its trailer. A photograph of this type of collection vehicle loading a stationary compactor is shown in Figure 13.
- Headquarters--The headquarters component of a commercial collection system is the same as that described for residential collection systems.
- Disposal Site--The disposal site component of a commercial collection system is the same as that described for residential collection systems.
- Collection Units--A collection vehicle of a commercial collection system serves only commercial collection units. A commercial collection unit is one or more fixed containers stationed at the site of a non-residential activity.

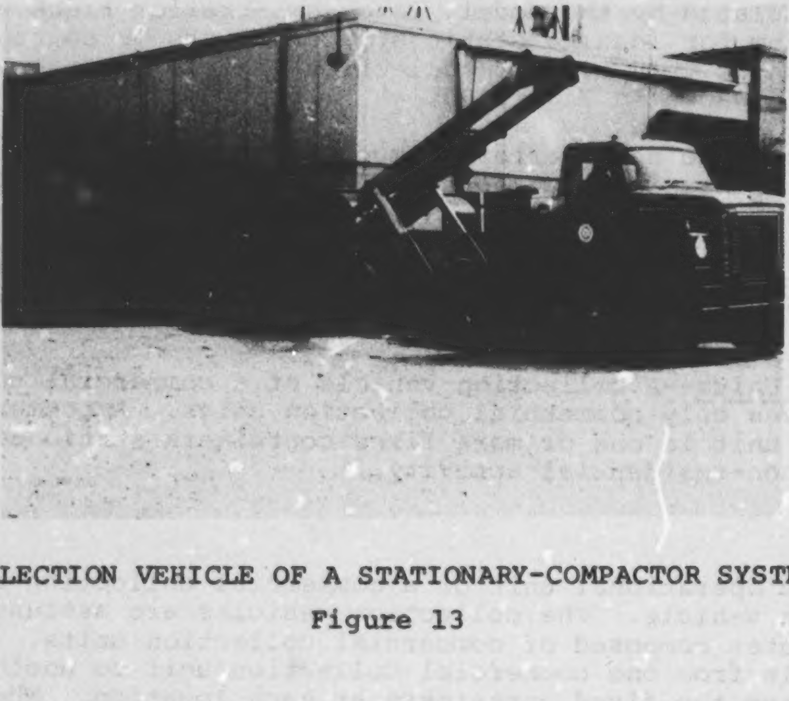
Operation

The basic operational unit of a commercial collection system is the collection vehicle. The collection vehicles are assigned specific collection routes composed of commercial collection units. A collection vehicle travels from one commercial collection unit to another collecting solid waste from the fixed containers at each location. When it is full



STATIONARY COMPACTOR

Figure 12



COLLECTION VEHICLE OF A STATIONARY-COMPACTOR SYSTEM

Figure 13

or its route is completed, a collection vehicle dumps the solid waste at a disposal site. The fundamental operational sequence of a commercial collection vehicle is shown in Figure 14.

SYSTEM PARAMETERS

System parameters are the variables of a system that can be controlled to improve the performance of the system. Each possible combination of system parameter values defines a particular system configuration or alternative. Since the primary purpose of the model is to simulate the performance of alternative solid waste collection systems, it has the flexibility to handle numerous practical sets of system parameter values for each of the types of residential and commercial collection systems it is designed to simulate.

In general, the model provides for changes in the values of the following collection system parameters:

- Number and location of headquarters
- Number and location of disposal sites
- Number of scales and dumping channels at each disposal site
- For each collection vehicle:
    - Capacity
    - Crew size
    - Collection route assignment
    - Headquarters assignment
    - Disposal site assignment
- Type of residential solid waste containers (cans or bags)
- Type of residential collection service provided (curb/alley pickup or carry-out)
- Frequency of collection (3 or 4 days since the last collection)

Thus, the model can be used to analyze several configurations of each type of collection system.

ENVIRONMENTAL FACTORS

Environmental factors are conditions which are independent of the configuration of a system but nevertheless influence its performance. Environmental factors of solid waste collection systems which are accounted for in the model are the following:

- Amount of solid waste generated on a collection route as a function of the nature and intensity of the land use activity along the route, the season of the year, and the frequency of collection.

- Collection network expressed in terms of the condition of links (paved or unpaved), the type of links (street or alley, one-side or two-side collection or non-collection) and the basic layout of the street/alley network (definition of street network areas).

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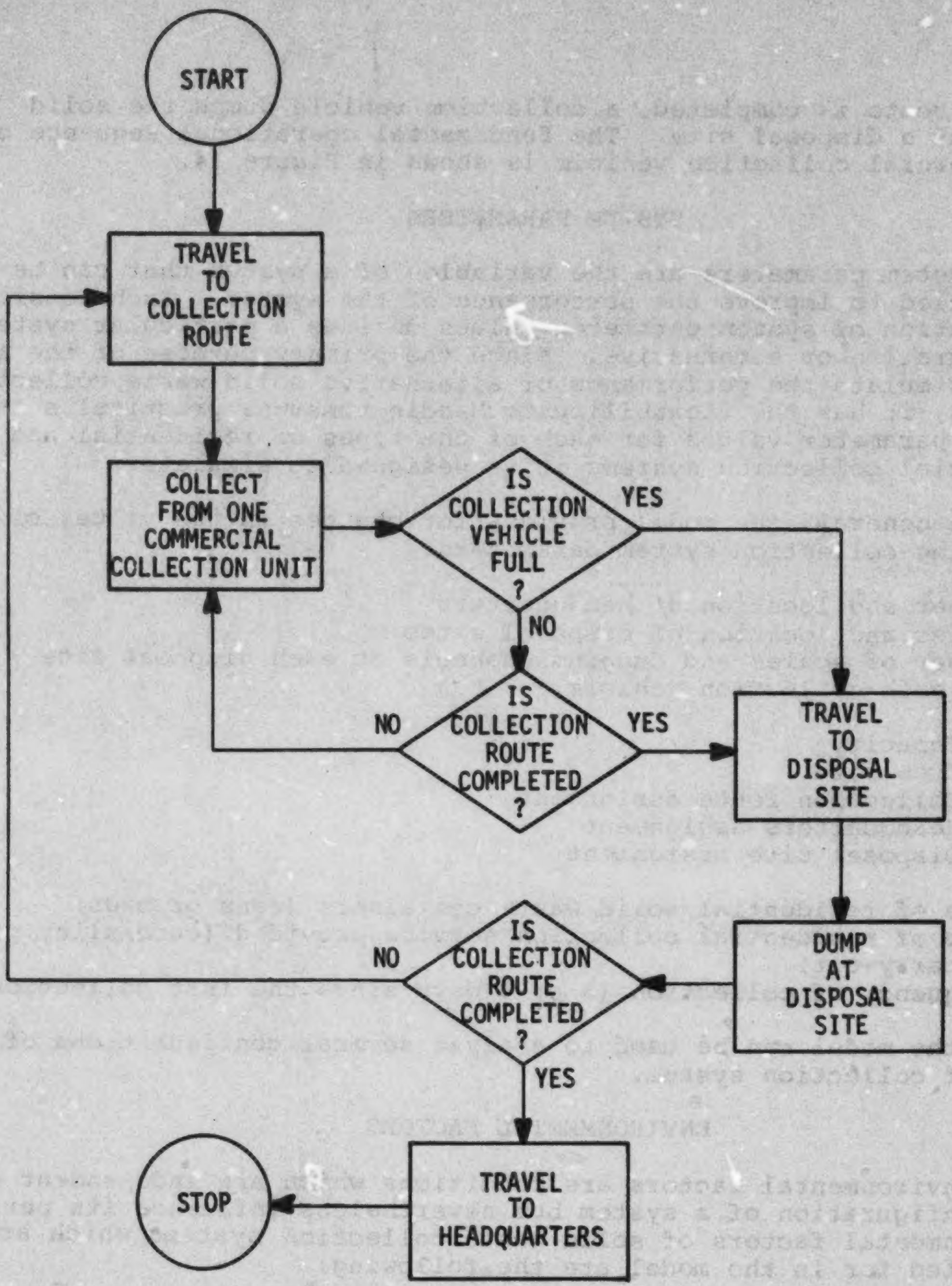

START
TRAVEL TO COLLECTION ROUTE
COLLECT FROM ONE COMMERCIAL COLLECTION UNIT
IS COLLECTION VEHICLE FULL ?
YES
NO
IS COLLECTION ROUTE COMPLETED ?
NO
YES
TRAVEL TO DISPOSAL SITE
DUMP AT DISPOSAL SITE
IS COLLECTION ROUTE COMPLETED ?
NO
YES
TRAVEL TO HEADQUARTERS
STOP

OPERATIONAL SEQUENCE OF A COLLECTION VEHICLE OF A COMMERCIAL COLLECTION SYSTEM

Figure 14

- Human factors as reflected in collection rates as a function of amount of solid waste to be collected and crew size.

In some cases, certain system parameters may be in effect environmental factors. For example, the number and locations of disposal sites in a particular situation may have been established and impossible for the planner-manager of the solid waste collection system to change. In such a case, the number and locations of disposal sites are in effect environmental factors. However, in any case, their effects on the performance of a collection system are accounted for by the model.

PERFORMANCE CHARACTERISTICS

The performance characteristics of a solid waste collection system are dependent on the values of the system parameters and environmental factors. Those included in the model to simulate the operation of solid waste collection systems are the following:

- Headquarters departure times
- Collection speeds
- Travel speeds
- Weighing times
- Dump times
- Breakdown rates, times of occurrence, and down times

Values of these performance characteristics for solid waste collection systems of the type that the model is designed to simulate are provided in the model. However, in order to make the model more general and able to better simulate particular collection systems, other values for these performance characteristics can be input to the model to be used instead of those already in the model.

MEASURES OF EFFECTIVENESS

Measures of effectiveness provide a basis for evaluating alternative systems and selecting the best one. Therefore, the results of a simulation output by the model include values for certain measures of effectiveness of solid waste collection systems. The principal measures of effectiveness output by the model are the following:

- Equipment miles
- Equipment hours
- Manhours

The values of these variables can then be used directly in a cost analysis of the collection system simulated.

CHAPTER III

INPUT PROGRAM MODULE

CHAPTER III

INPUT PROGRAM MODULE

FUNCTION

The input to the model is a deck of data cards which defines the collection system and conditions to be simulated. The function of the Input Program Module is to edit the data deck and generate a tape to be input to the Simulation Program Module. The Input Program Module first checks to determine whether or not the data deck meets certain input data requirements. If the data deck satisfies these requirements, the Input Program Module records the data on a tape which is input to the Simulation Program Module. However, if the data deck fails to satisfy the requirements, the Input Program Module prints edit messages that indicate location and nature of the data deck errors. The data deck can then be corrected and again input to the Input Program Module to build the input tape.

DATA DECK

The data deck consists of the following 15 data sets:

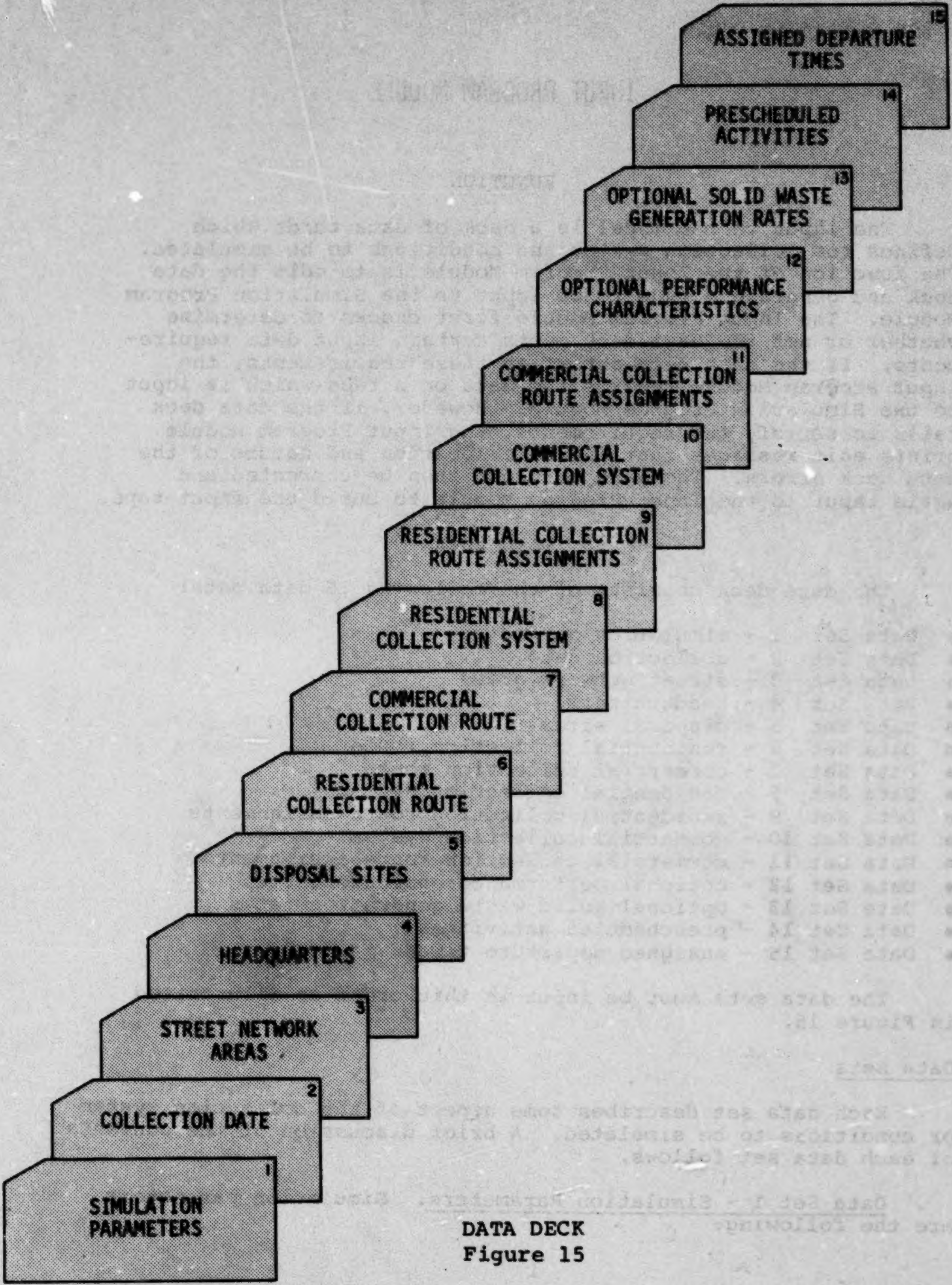
- Data Set 1 - simulation parameters
- Data Set 2 - collection date
- Data Set 3 - street network areas
- Data Set 4 - headquarters
- Data Set 5 - disposal sites
- Data Set 6 - residential collection route
- Data Set 7 - commercial collection route
- Data Set 8 - residential collection system
- Data Set 9 - residential collection route assignments
- Data Set 10 - commercial collection system
- Data Set 11 - commercial collection route assignments
- Data Set 12 - optional performance characteristics
- Date Set 13 - optional solid waste generation rates
- Data Set 14 - prescheduled activities
- Data Set 15 - assigned departure times

The data sets must be input in this order as illustrated in Figure 15.

Data Sets

Each data set describes some aspect of the collection system or conditions to be simulated. A brief discussion of the contents of each data set follows.

Data Set 1 - Simulation Parameters. Simulation parameters are the following:


15
ASSIGNED DEPARTURE TIMES
14
PRESCHEDULED ACTIVITIES
13
OPTIONAL SOLID WASTE GENERATION RATES
12
OPTIONAL PERFORMANCE CHARACTERISTICS
11
COMMERCIAL COLLECTION ROUTE ASSIGNMENTS
10
COMMERCIAL COLLECTION SYSTEM
9
RESIDENTIAL COLLECTION ROUTE ASSIGNMENTS
8
RESIDENTIAL COLLECTION SYSTEM
7
COMMERCIAL COLLECTION ROUTE
6
RESIDENTIAL COLLECTION ROUTE
5
DISPOSAL SITES
4
HEADQUARTERS
3
STREET NETWORK AREAS
2
COLLECTION DATE
1
SIMULATION PARAMETERS

DATA DECK
Figure 15

- Report number and other alphanumeric information that are used to identify the output of the simulation

- Number of simulation iterations

Number of iterations is the number of times that the simulation is to be repeated during the simulation run. The average of the collection system performances for the simulation iterations is output as the collection system performance for the simulation run. Thus, in effect the number of iterations is the number of collection days of collection system operation under the given set of collection conditions that are used to determine the average performance of the collection system for a collection day.

Data Set 2 - Collection Date. The collection date refers to the month of the year and number of days since the last collection for which the simulation is to be conducted. It is an environmental factor that can affect the amount of solid waste generated and consequently the performance of the collection system. Inputs that define the collection date are the following:

- Month of the year
- Number of days since the last collection

Data Set 3 - Street Network Areas. A street network area is a portion of a street network within which the travel distance from any node to any other node can be assumed to be equal to the "Metric L" distance between them. The number of street network areas depends on the configuration of the particular street network involved. Inputs that describe the street network areas are the following:

- Number of street network areas

- X-Y coordinates of the nodes at the boundaries of the street network areas through which trips between each pair of street network areas are made

- Travel distances between the boundary nodes

Data Set 4 - Headquarters. A headquarters is where collection vehicles are stationed. A collection vehicle leaves its headquarters at the beginning of its collection day and returns to its headquarters at the end of its collection day. Inputs that describe the headquarters are the following:

- Number of headquarters
- X-Y coordinates of each headquarters

- Identification number of the street network area within which each headquarters is located

Data Set 5 - Disposal Sites. A disposal site is where solid waste collected is hauled and dumped from collection vehicles for disposal and/or processing. This location may be a transfer station, landfill site, incinerator, or some other type of solid waste disposal and/or processing facility. Inputs that describe the disposal sites are the following:

- Number of disposal sites
- X-Y coordinates of each disposal site
- Identification number of the street network area within which each disposal site is located
- Number of scales at each disposal site
- Number of dumping channels at each disposal site, which is the number of collection vehicles that can dump at any one time at each disposal site

Data Set 6 - Residential Collection Route. The residential collection route consists of all of the collection links plus the non-collection links necessary to form a single continuous route. The links are numbered sequentially starting with the beginning of the route as number one. Inputs that describe the residential collection route are the number of links and the following data for each link:

- Sequence number of the link
- Node number at which the link ends (BNODE)
- X-Y coordinates of BNODE
- Identification number of the street network area within which BNODE is located
- Length of the link
- Number of residential units on the link
- Average floor area per residential unit on the link
- Average number of persons per residential unit on the link
- Average income per residential unit on the link
- Number of residential units on the link that receive carry-out service
- Type of carry-outs which indicates the carry-out distance.
- Link code which indicates if the link is a street with one-side or two-side collection or an alley with one-side or two-side collection
- Link surface code which indicates if the link is paved or unpaved

The nature of a residential collection route as defined by these link data affects the amount of solid waste to be collected and the performance of the collection system.

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Data Set 7 - Commercial Collection Route. The commercial collection route contains all of the commercial collection units to form one continuous commercial collection route. The collection units are numbered sequentially starting with the beginning of the route as number one. Inputs that describe the commercial collection route are the number of collection units and the following data for each collection unit:

- Sequence number of the collection unit
- Node number at which the collection unit is located
- X-Y coordinates of the collection unit's location
- Identification number of the street network area within which the collection unit is located
- Number and size of collection unit's fixed containers

The number and size of the fixed containers of a collection unit are used to determine the amount of solid waste to be collected at the collection unit and the length of time it takes to collect it.

Data Set 8 - Residential Collection System. The residential collection system consists of the collection vehicles which collect solid waste on the residential collection route. The model can simulate the operation of the following types of residential collection systems:

- Container-train systems
- Packer-truck systems
- Alley/street-container systems
- Mechanical-bag-retriever systems

Inputs that describe the residential collection system are the type of residential collection system, the number of collection vehicles in the system, and the following data for each collection vehicle:

- Identification number
- Capacity
- Crew size
- Identification numbers of its headquarters and disposal site

In the case of a container-train system, the inputs also include the identification number of each train's container transfer vehicle. The type of residential solid waste container (can or bag) is also included in the case of a container-train system or a packer-truck system. And, for an alley/street-container system, the inputs include the average number of residential units assigned to an alley/street container.

Data Set 9 - Residential Collection Route Assignments. Each residential collection vehicle (other than the container transfer vehicles of a container-train system) is assigned a continuous portion of the residential collection route to collect, which is referred to as a residential collection route assignment. Inputs that describe the residential collection route assignment of a collection vehicle are the sequence numbers of the first and last links on its route.

Data Set 10 - Commercial Collection System. The commercial collection system consists of the collect vehicles which collect solid waste on the commercial collection route. The model can simulate the operation of the following types of commercial collection systems:

- Container-transfer-vehicle systems
- Packer-truck systems

Inputs that describe the commercial collection system are the type of commercial system, the number of collection vehicles in the system, and the following data for each collection vehicle:

- Identification number
- Capacity
- Crew size
- Identification numbers of its headquarters and disposal site

Data Set 11 - Commercial Collection Route Assignments. Each commercial collection vehicle and usually each container transfer vehicle of a container-train, residential collection system are assigned a continuous portion of the commercial collection route to collect, which is referred to as a commercial collection route assignment. Inputs that describe the commercial collection route assignment of a collection vehicle are the sequence numbers of the first and last collection units on its route.

Data Set 12 - Optional Performance Characteristics. The performance characteristics of a collection vehicle determine its operation during the collection day. In the model, the performance characteristics that define the operation of collection vehicles are the following:

- Departure times
- Collection times per residential unit
- Additional collection times per carry-out
- Non-collection speeds
- Container dump times

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- Travel speeds
- Weighing times
- Dump times
- Frequencies, times of occurrence, and durations of breakdowns

These performance characteristics are expressed in the form of cumulative histograms. From the results of a study of performance characteristics of collection vehicles of the types that the model is designed to simulate, cumulative histograms for these performance characteristics were constructed and are provided in the model. (These cumulative histograms are presented in Appendix I.) However, in order to make the model more general and able to better simulate particular collection systems, other cumulative histograms of the performance characteristics can be input as optional performance characteristics to be used instead of those already in the model. Inputs that describe each of these cumulative histograms are the following:

- Data which indicate the particular performance characteristics represented

- Minimum and maximum values of the performance characteristic

- Number of equal-sized intervals into which range of values is divided

- Cumulative probabilities for the intervals

Data Set 13 - Optional Solid Waste Generation Rates. Solid waste generation rates refer to the amounts of solid waste that are to be collected along residential collection links and from commercial collection units. From the results of a study of solid waste generation, cumulative histograms of solid waste generation rates for four residential neighborhood types and three sizes of fixed containers were constructed and are provided in the model. (These cumulative histograms are presented in Appendix I.) However, in order to make the model more general and able to better simulate particular situations, other cumulative histograms of solid waste generation rates can be input as optional solid waste generation rates to be used instead of those already in the model. Inputs that describe each of the cumulative histograms are the following:

- Solid waste generation rate code that indicates the neighborhood type of fixed container size represented

- Minimum and maximum values of the solid waste generation rate

- Number of equal-sized intervals into which range of values is divided

- Cumulative probabilities for the intervals

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Data Set 14 - Prescheduled Activities. A prescheduled activity is an activity of a collection vehicle that is scheduled before the collection day begins to occur at a particular time. Prescheduled activities are non-collection activities such as lunch breaks and routine maintenance stops. Inputs that describe the prescheduled activities are the number of prescheduled activities to be input and the following for each of them:

- Identification number of the collection vehicle involved
- Time of occurrence
- Duration
- Distance traveled by the collection vehicle involved

Data Set 15 - Assigned Departure Times. A departure time is the time of day at which a collection vehicle leaves its headquarters to begin its collection day. The departure times of the collection vehicles in a collection system being simulated are either determined by the model or assigned by the user. If they are not assigned, the model determines them using either departure time characteristics provided in the model or some which are input as optional performance characteristics. If they are assigned, they are input as assigned departure times. Inputs that describe each assigned departure time are the following:

- Identification of headquarters
- Type of collection vehicle
- Departure time (time of day)

The set of assigned departure times must include a departure time for each combination of headquarters and collection vehicle type.

Data Deck Cards

Most of the data sets are composed of a data control card followed by a number of data cards. The data control card contains the number of elements in the data set and any general data items that pertain to all elements of the data set. A data card contains data items that refer to a particular element of the data set. For example, in Data Set 4, the first card is a data control card, which contains the number of headquarters, and the remaining cards are data cards, one for each headquarters, which contains the X-Y coordinates and street-network-area number of the headquarters.

There are four exceptions to the data set composition described above. Data Sets 1 and 2 each consist of only data control cards and do not contain any data cards. Data Sets 8 and 10 each have two data control cards instead of just one.

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The formats of the data deck cards for each data set are presented in Appendix II. Each card contains a card code which is used by the Input Program Module in editing the data deck. The card codes and data requirements, which are also used to edit the data deck, are specified together with the card formats in Appendix II.

DATA EDIT

The Input Program Module edits the data deck to determine whether or not it satisfies the specified data requirements. Each card in the data deck is checked. If it contains data errors, its data are printed out together with edit codes which indicate the location and nature of the errors. These error messages can be utilized to correct the data deck for resubmission to the Input Program Module. When the Input Program Module determines that the data deck does not contain any errors, it outputs the data deck on a tape for input to the Simulation Program Module.

An example of the error messages output by the Input Program Module is shown in Figure 16. The first two lines at the top of each page of output are the card column numbers (01-79). Then, two lines are printed for each card that contains an error. The first line contains the data that are punched in the card. The second line contains edit codes which indicate the location and nature of each error. The edit codes are defined in Appendix III for each card code.

The output in Figure 16 lists 14 cards that were found to contain errors. The card codes (punched in card columns 01-03) of these cards are: 062, 072, 111, 121, and 142. The location of the error in each card is indicated by the edit codes printed under the card data line in the erroneous data card columns. And, the nature of the error is determined by referring to the edit code definitions given in Appendix III for the particular card code. The interpretation of the errors indicated in Figure 16 is as follows:

Card Code	Card Cols.	Edit Code	Error
062	15-17	H	ID no. of (train's) container transfer vehicle not valid
072	5-7	D	ID no. of collection vehicle (container transfer vehicle) not valid
111	5-8	D	count (no. of residential collection route assignments) not valid
121	5-8	D	count (no. of collection vehicles) not valid
142	5-7	E	ID no. (of collection vehicle) not consecutive

```
0 0 0 0 0 1 1 1 1 1 2 2 2 2 2 3 3 3 3 3 4 4 4 4 4 5 5 5 5 5 6 6 6 6 6 7 7 7 7 7
1 3 5 7 9 1 3 5 7 9 1 3 5 7 9 1 3 5 7 9 1 3 5 7 9 1 3 5 7 9 1 3 5 7 9 1 3 5 7 9

062 01005000430051
              HHH

062 02005000430061
              HHH

062 03005000430072
              HHH

062 04005000430082
              HHH

072 005005000111
    DDD

072 006005000111
    DDD

072 007005000111
    DDD

072 008005000111
    DDD

111 0004
    DDDD

121 0000
    DDDD

142 00500010005
    EEE

142 00600060010
    EEE

142 00700110015
    EEE

142 00800160020
    EEE
```

EDIT PROGRAM OUTPUT

Figure 16

The data requirements which must be satisfied to eliminate data errors are specified together with the card formats in Appendix II.

LOGIC

The basic logic of the Input Program Module consists of the following steps, beginning with the first card in the data deck:

(1) Read a card.

(2) Determine the card code on the card.

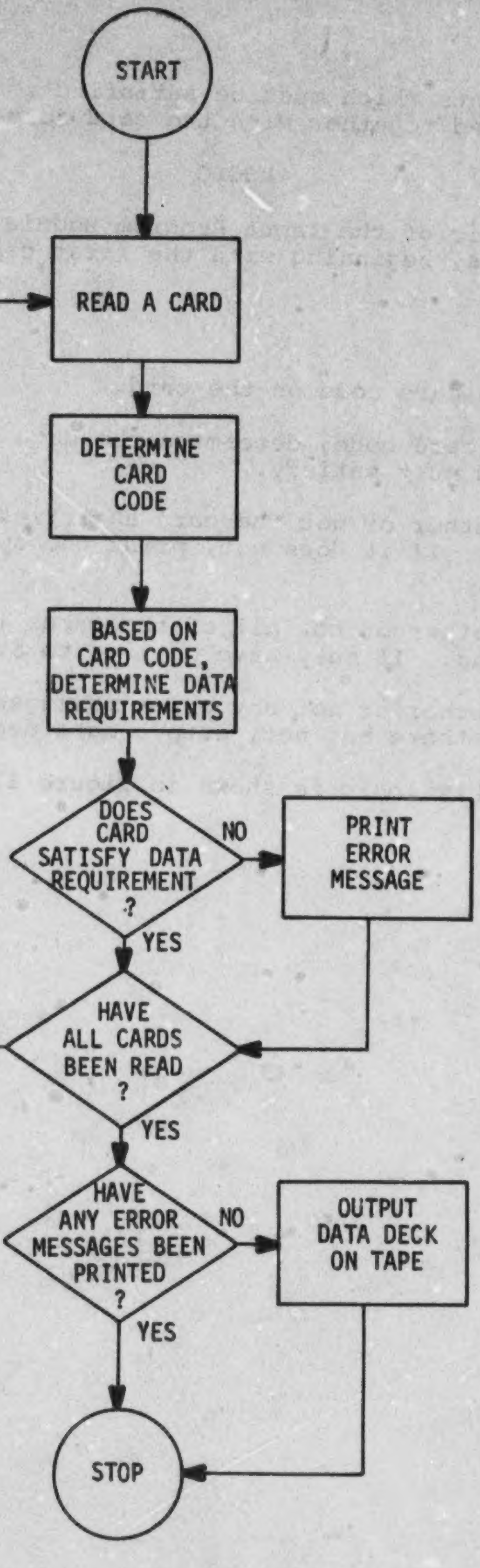
(3) Based on the card code, determine the data requirements that the card must satisfy.

(4) Determine whether or not the card satisfies its data requirements. If it does not, print the appropriate error message.

(5) Determine whether or not all of the cards in the data deck have been read. If they have not, go to Step 1.

(6) Determine whether or not any error messages have been printed. If there has not, output data deck on a tape.

A flow chart of this logic is shown in Figure 17.


START
READ A CARD
DETERMINE CARD CODE
BASED ON CARD CODE, DETERMINE DATA REQUIREMENTS
DOES CARD SATISFY DATA REQUIREMENT ?
NO
PRINT ERROR MESSAGE
YES
HAVE ALL CARDS BEEN READ ?
NO
YES
HAVE ANY ERROR MESSAGES BEEN PRINTED ?
NO
OUTPUT DATA DECK ON TAPE
YES
STOP

BASIC LOGIC OF INPUT PROGRAM MODULE

Figure 17

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CHAPTER IV

SIMULATION PROGRAM MODULE

(44) blank

SIMULATION PROGRAM MODULE

FUNCTION

The function of the Simulation Program Module is to calculate the performance of the collection system to be simulated. It reads a description of the collection system and conditions to be simulated from the tape generated by the Input Program Module. Then, it calculates the performance of the collection system and generates a summary of the performance on a tape to be input to the Output Program Module.

The performance of a collection system is determined by integration of the operational sequences of the collection vehicles to obtain a description of the collection system's operation. (The operational sequences of the collection vehicles of collection systems that can be simulated by the model are described in Chapter II.) The integration of operational sequences involves the construction of a daily calendar which designates the chronological sequence of events that mark the start of each activity during the system's collection day. Associated with each event on the calendar are the following information:

- Time at which it occurs
- Type of activity which is to start
- Identification number of the collection vehicle involved

In general, the time of occurrence of an event is computed by adding the duration of the collection vehicle's preceding activity to the time of occurrence of its preceding event. The type of activity is determined in accordance with the collection vehicle's operational sequence.

Starting with the earliest event on the calendar (which marks the beginning of the collection day), the duration of the subsequent activity and values of variables, which depict the performance of the activity by the collection vehicle involved, are calculated. The performance data are used to update the daily performance statistics of the collection vehicle. The type and time of occurrence of the collection vehicle's next event are determined, and it is placed on the calendar. This procedure is repeated for the next event on the calendar and continued until there are no more events remaining on the calendar (which marks the end of the collection day). At the end of the collection day, the performance statistics are summarized for output.

COMPONENTS

The Simulation Program Module is composed of the following components:

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- Main Program
- Event Table
- Clock
- Activity Subprograms
- Utility Subprograms

A brief discussion of each of these components follows.

Main Program

The Main Program provides interfaces between the Simulation Program Module and the Input/Output Modules. Also, it controls the simulation by coordinating the operations of the other components of the Simulation Program Module. A schematic depicting the Main Program's interaction with the other components of the Simulation Program and the Input/Output Program Modules is shown in Figure 18.

The Main Program reads a description of the collection system and conditions to be simulated from a tape provided by the Input Program Module. It then synchronizes the operation of the Simulation Program Module by maintaining the Event Table and timing the Clock in accordance with the operational sequences of the collection vehicles involved and the durations of their collection activities as computed by the Activity Subprograms. When it is time for an event to occur, the Main Program removes it from the Event Table and calls the appropriate Activity Subprogram to determine the duration of the associated activity and the performance of the collection vehicle involved. Next, it determines the time of occurrence and type of the collection vehicle's next event and has it placed in the Event Table. Then, it advances the Clock to the time of occurrence of the next most imminent event in the Event Table and repeats the procedure. When all of the events have been removed from the Event Table and processed, the Main Program summarizes the collection system's performance on a tape to be input to the Output Program Module.

The Main Program is discussed in more detail in Chapter V.

Event Table

The Event Table contains the collection system's calendar of events for the collection day. The time of occurrence of each event is stored in chronological order along with the type of the activity associated with it and the identification number of the collection vehicle involved.

Clock

The Clock measures the time of the collection day. The time on the Clock is initially set equal to the time of occurrence of the earliest event in the Event Table. When all computations pertaining to the event have been executed, the event is said to have occurred. The Clock is then advanced by the Main Program to the time of occurrence

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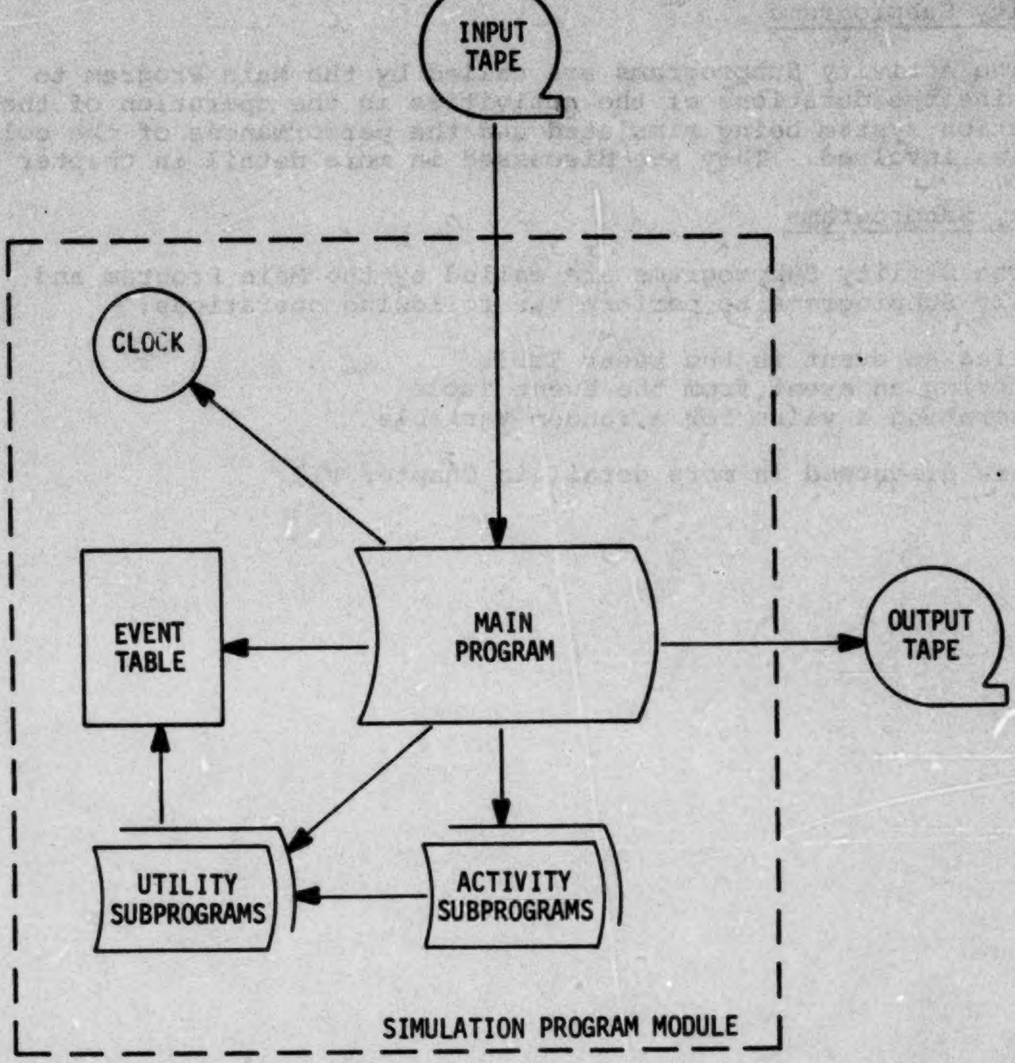
INPUT TAPE
CLOCK
EVENT TABLE
MAIN PROGRAM
OUTPUT TAPE
UTILITY SUBPROGRAMS
ACTIVITY SUBPROGRAMS
SIMULATION PROGRAM MODULE

SCHEMATIC OF SIMULATION PROGRAM MODULE

Figure 18

of the next most imminent event. The Clock is similarly incremented until the last event of the day has occurred.

Activity Subprograms

The Activity Subprograms are called by the Main Program to determine the durations of the activities in the operation of the collection system being simulated and the performances of the collection vehicles involved. They are discussed in more detail in Chapter VI.

Utility Subprograms

The Utility Subprograms are called by the Main Program and Activity Subprograms to perform the following operations:

- Filing an event in the Event Table
- Removing an event from the Event Table
- Generating a value for a random variable

They are discussed in more detail in Chapter VII.

CHAPTER V

MAIN PROGRAM

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MAIN PROGRAM

FUNCTION

The function of the Main Program is the following:

- To provide interfaces between the Simulation Program Module and the Input/Output Program Modules
- To coordinate the operations of the other components of the Simulation Program Module

The Main Program receives a description of the collection system and conditions to be simulated from the Input Program Module. It then synchronizes the operation of the Simulation Program Module by maintaining the Event Table and timing the Clock in accordance with the operational sequences of the collection vehicles involved and the durations of their collection activities as computed by the Activity Subprograms. Finally, it summarizes the performance of the collection system as computed by the Activity Subprograms and provides the summary as input data to the Output Program Module.

LOGIC

The logic of the Main Program is comprised of the following sets of logic:

- Input/output logic
- Control logic

This logic is presented in the flow chart in Appendix IV.

Input/Output Logic

The input/output logic provides the interfaces between the Simulation Program Module and the Input/Output Program Modules. It reads the input tape, which is generated by the Input Program Module and which describes the collection system and conditions to be simulated; and it initializes the performance statistics of the collection system and certain simulation variables. Also, this set of logic accumulates and summarizes the performance statistics of the collection system and records these data on a tape for input to the Output Program Module.

Control Logic

The control logic coordinates the functions of the Clock, Event Table, Activity Subprograms, and Utility Subprograms to predict the performance of the collection system being simulated for a collection day under the conditions specified. The following are the fundamental steps of the control logic:

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(1) Call the Breakdown Subroutine I to determine for each collection vehicle the number of breakdowns to occur during the collection day; and to determine for each collection vehicle, for which the number of breakdowns is not equal to zero, the time of occurrence of its first breakdown and to file this event in the Event Table.

(2) Call the Prescheduled Activities Subroutine I to file in the Event Table the first prescheduled activity of each collection vehicle that has at least one prescheduled activity.

(3) Call the Departure Subroutine to determine for each collection vehicle the time at which it leaves its headquarters and to file this event in the Event Table.

(4) Remove the earliest event from the Event Table and set the time on the Clock equal to this event's time of occurrence.

(5) Determine the type of event which has been removed from the Event Table and call the appropriate Activity Subprogram to compute the performance of the activity associated with it.

(6) Update the performance statistics of the collection vehicle involved in the associated activity.

(7) Determine whether or not the collection vehicle has completed its collection day; and, if it has not, determine the type and time of occurrence of its next event and file this event in the Event Table.

(8) Repeat Steps 4 through 7 until all of the events have been removed from the Event Table.

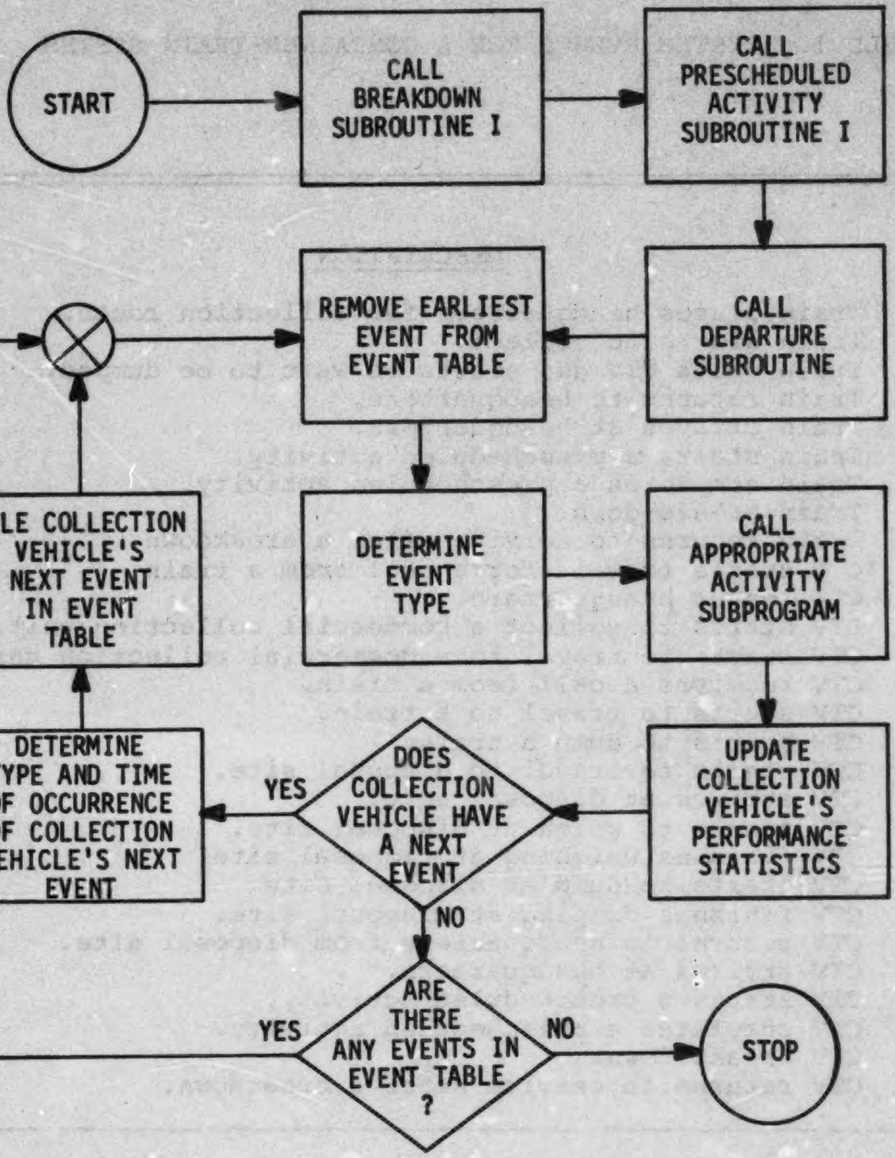
A flow chart of the fundamental control logic is shown in Figure 19.

The control logic is divided into three logic subsets as follows:

- Container-train system logic
- Other residential collection system logic
- Commercial collection system logic

Each of these logic subsets utilizes the fundamental steps of the control logic, but each uses a different operational sequence for ordering the generation of system events. Consequently, the logic subset used in a particular simulation depends on the type of collection system being simulated.

Container-Train System Logic. The container-train system logic (CTSL) uses the operational sequences of the container-train system, shown in Figures 5 and 6, for ordering the occurrence of system events, which are presented in Table 1. A discussion of CTSL in terms of these system events follows.


START
CALL BREAKDOWN SUBROUTINE I
CALL PRESCHEDULED ACTIVITY SUBROUTINE I
CALL DEPARTURE SUBROUTINE
REMOVE EARLIEST EVENT FROM EVENT TABLE
DETERMINE EVENT TYPE
CALL APPROPRIATE ACTIVITY SUBPROGRAM
UPDATE COLLECTION VEHICLE'S PERFORMANCE STATISTICS
DOES COLLECTION VEHICLE HAVE A NEXT EVENT
YES
NO
DETERMINE TYPE AND TIME OF OCCURRENCE OF COLLECTION VEHICLE'S NEXT EVENT
FILE COLLECTION VEHICLE'S NEXT EVENT IN EVENT TABLE
ARE THERE ANY EVENTS IN EVENT TABLE ?
YES
NO
STOP

FUNDAMENTAL CONTROL LOGIC OF MAIN PROGRAM

Figure 19

TABLE 1. SYSTEM EVENTS FOR A CONTAINER-TRAIN SYSTEM

EVENT TYPE	DESCRIPTION
1	Train leaves headquarters for collection route.
2	Train starts to collect.
3	Train calls CTV and starts to wait to be dumped.
4	Train returns to headquarters.
5	Train arrives at headquarters.
6	Train starts a prescheduled activity.
7	Train completes a prescheduled activity.
8	Train breaks down.
9	Train returns to service after a breakdown.
10	*CTV starts to wait for a call from a train.
11	CTV leaves headquarters.
12	CTV starts to collect a commercial collection unit.
13	CTV starts to travel to a commercial collection unit.
14	CTV receives a call from a train.
15	CTV starts to travel to a train.
16	CTV starts to dump a train.
17	CTV starts to travel to disposal site.
18	CTV arrives at disposal site.
19	CTV starts to weigh at disposal site.
20	CTV finishes weighing at disposal site.
21	CTV starts to dump at disposal site.
22	CTV finishes dumping at disposal site.
23	CTV returns to headquarters from disposal site.
24	CTV arrives at headquarters.
25	CTV starts a prescheduled activity.
26	CTV completes a prescheduled activity.
27	CTV breaks down.
28	CTV returns to service after a breakdown.

*CTV - container transfer vehicle

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- Event Type 1--When an Event Type 1 is removed from the Event Table, CTSL calls the Travel Subroutine to compute (1) the length of time it takes the train involved to travel from its headquarters to its collection route, and (2) the distance it travels. The travel time is added to the train's total travel time and the distance traveled is added to the train's total distance traveled. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 2 for the train with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 2--For an Event Type 2, CTSL calls the Collection Subroutine I to determine the following performance statistics for the train involved:

    - Amount of solid waste collected
    - Collection time
    - Collection distance
    - Non-collection time
    - Non-collection distance
    - Number of residential units served
    - Floor area of residential units served
    - Number of persons in residential units served
    - Income of residential units served
    - Number of carry-outs by type

    These statistics are added to their respective totals for the train. Then, CTSL calls the File Subroutine to enter into the Event Table and Event Type 3 for the train with a time of occurrence equal to the time on the Clock plus the collection and non-collection times.

- Event Type 3--For an Event Type 3, CTSL places the train involved into its convoy's queue of trains waiting to be dumped by the convoy's container transfer vehicle (CTV). Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 14 for the CTV with a time of occurrence equal to the time on the Clock.

- Event Type 4--For an Event Type 4, CTSL calls the Travel Subroutine to compute (1) the length of time it takes the train involved to travel from the end of its collection route to its headquarters, and (2) the distance it travels. The travel time and distance traveled are added to their respective totals for the train. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 5 for the train with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 5--Event Type 5 marks the arrival of the train involved back at its headquarters and the end of its collection day. Therefore, CTSL checks to see if there are any events left in the Event Table. If there is, CTSL removes the earliest event from the Event Table and continues with the simulation. If there is not, the collection system has completed its collection day, and CTSL transfers control to the input/output logic for generation of the input tape to the Output Program Module.

- Event Type 6--If the train involved is broken down when an Event Type 6 for it is removed from the Event Table, CTSL searches the Event Table to find the time when the train will return to service and calls the File Subroutine to enter into the Event Table an Event Type 6 for the train with a time of occurrence equal to the time when the train will return to service.

  If the train involved is not broken down, CTSL determines whether or not the train is waiting to be dumped. If it is waiting to be dumped, CTSL determines how long it has been waiting, and calls the Prescheduled Activities Subroutine II to determine the duration of the prescheduled activity and any distance traveled by the train during the prescheduled activity. These performance statistics are added to their respective totals for the train. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 7 for the train with a time of occurrence equal to the time on the Clock plus the duration of the prescheduled activity.

  If the train is not waiting to be dumped, CTSL searches the Event Table to find the train's next event other than a "breakdown" event (Event Type 8). If the train does not have such a next event, its collection day is over and CTSL cancels the prescheduled activity. Otherwise, CTSL calls the Remove Subroutine to remove the train's next event from the Event Table, and calls the Prescheduled Activities Subroutine II to determine the duration of the prescheduled activity and any distance traveled by the train during the prescheduled activity. These performance statistics are added to their respective totals for the train. Then, CTSL calls the File Subroutine to enter the following events into the Event Table:

  - The next event type for the train with a time of occurrence equal to either (1) the time of occurrence of the train's next event plus the duration of the prescheduled activity, or (2) the time of the Clock plus the duration of the prescheduled activity, if the train's next event type is an Event Type 1.

  - An Event Type 7 for the train with a time of occurrence equal to the time on the Clock plus the duration of the prescheduled activity

- Event Type 7--For an Event Type 7, CTSL first determines whether or not the train involved in the prescheduled activity just completed was waiting to be dumped when it started the prescheduled activity. If the train was not waiting to be dumped, CTSL calls the Prescheduled Activities Subroutine III to determine (1) whether or not the train has another prescheduled activity; and (2) if it does, the time of occurrence of its next prescheduled activity. If the Prescheduled Activities Subroutine III determines that the train does have another prescheduled activity, CTSL calls the File Subroutine to enter into the Event Table an Event Type 6 for the train with a time of occurrence equal to that determined by the Prescheduled Activities Subroutine III. If the Prescheduled Activities Subroutine III determines that the train does not have another prescheduled activity, CTSL merely continues with the simulation.

If the train was waiting to be dumped, CTSL determines whether or not the train was dumped during the prescheduled activity. If the train was dumped, CTSL calls the Prescheduled Activities Subroutine III and continues as in the case where the train had not been waiting to be dumped. If the train was not dumped, CTSL initializes the train's wait to be dumped, and then, calls the Prescheduled Activities Subroutine III and continues as in the case where the train had not been waiting to be dumped.

- Event Type 8--For an Event Type 8, CTSL calls the Breakdown Subroutine II to determine how long the train involved will be broken down. CTSL compares the down time to the specified replacement time (maximum allowable down time before replacement), and if the down time is greater than the replacement time, the train is replaced and the down time is set equal to the replacement time. Next, CTSL determines whether or not the train is waiting to be dumped. If it is waiting to be dumped, CTSL determines how long it has been waiting. The time waiting to be dumped and the down time are added to their respective totals for the train. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 9 for the train with a time of occurrence equal to the time on the Clock plus the down time.

  If the train is not waiting to be dumped, CTSL searches the Event Table to find the train's next event other than the start of a prescheduled activity (Event Type 6). If the next event found for the train is an Event Type 7, CTSL calls the Remove Subroutine to remove it from the Event Table, and then calls the File Subroutine to put the Event Type 7 for the train back into the Event Table with a time of occurrence equal to its previous time of occurrence plus the down time. CTSL continues to search the Event Table until it finds a next event for the train which is neither an Event Type 6 nor an Event Type 7. If the train does not have such a next event, its collection day is over and CTSL cancels the breakdown. Otherwise, when it finds such a next event, CTSL calls the Remove Subroutine to remove it from the Event Table. The down time is added to the total down time for the train. Then, CTSL calls the File Subroutine to enter the following events into the Event Table:

  - The next event for the train with a time of occurrence equal to the time of occurrence of the train's next event plus the down time

  - An Event Type 9 for the train with a time of occurrence equal to the time on the Clock plus the down time

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- Event Type 9--For an Event Type 9, CTSL first determines whether or not the train involved in the breakdown was waiting to be dumped when it broke down. If the train was not waiting to be dumped, CTSL calls the Breakdown Subroutine III to determine (1) whether or not the train is to have another breakdown; and (2) if it is, the time of occurrence of its next breakdown. If the Breakdown Subroutine III determines that the train does have another breakdown, CTSL calls the File Subroutine to enter into the Event Table an Event Type 8 for the train with a time of occurrence equal to that determined by the Breakdown Subroutine III. If the Breakdown Subroutine III determines that the train does not have another breakdown, CTSL merely continues with the simulation.

  If the train was waiting to be dumped, CTSL determines whether or not the train was dumped during the time it was broken down. If the train was dumped, CTSL calls the Breakdown Subroutine III and continues as in the case where the train had not been waiting to be dumped. If the train was not dumped, CTSL initializes the train's wait to be dumped, and then, CTSL calls the Breakdown Subroutine III and continues as in the case where the train had not been waiting to be dumped.

- Event Type 10--Event Type 10 marks the time when a container transfer vehicle (CTV) starts to wait for a call from a train. The CTV has completed its commercial collection route and must wait for the trains in its convoy to complete their routes so that it can dump them before returning to headquarters. CTSL initializes the CTV's wait for a call.

- Event Type 11--For an Event Type 11, CTSL first determines whether or not a train in the convoy of the CTV involved is waiting to be dumped. If not, CTSL determines whether or not the CTV has a commercial collection route. If the CTV has a commercial collection route, CTSL calls the Travel Subroutine to compute (1) the length of time it takes the CTV to travel from its headquarters to its commercial collection route, and (2) the distance it travels. The travel time and the distance traveled are added to their respective totals for the CTV. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 12 for the CTV with a time of occurrence equal to the time on the Clock plus the travel time. But, if the CTV does not have a commercial collection route,CTSL calls the File Subroutine to enter into the Event Table an Event Type 10 for the CTV with a time of occurrence equal to the time on the Clock.

  If a train in the CTV's convoy is waiting to be dumped, CTSL calls the File Subroutine to enter into the Event Table an Event Type 15 for the CTV with a time of occurrence equal to the time on the Clock.

- Event Type 12--For an Event Type 12, CTSL calls the Collection Subroutine II to determine (1) the amount of solid waste collected, (2) the collection time, and (3) the number of fixed containers dumped. These performance statistics are added to their respective totals for the CTV involved. Then, CTSL calls the File Subroutine to enter into the Event Table an event for the CTV with a time of occurrence equal to the time on the Clock plus the collection time. CTSL determines the type of the event to be filed in accordance with the following rules:
    - If the CTV is full, file Event Type 17.
    - If the CTV is not full and a train in its convoy is waiting to be dumped, file Event Type 15.
    - If the CTV is not full and there are not any trains in its convoy waiting to be dumped but is has not completed its commercial collection route, file Event Type 13.
    - If the CTV is not full and there are not any trains in its convoy waiting to be dumped but it has completed its commercial collection route and all the trains in its convoy have completed their collection routes, file Event Type 17.
    - If the CTV is not full and there are not any trains in its convoy waiting to be dumped and it has completed its commercial collection route but all the trains in its convoy have not completed their collection routes, file Event Type 10.
- Event Type 13--For an Event Type 13, CTSL first determines whether or not a train in the convoy of the CTV involved is waiting to be dumped. If not, CTSL calls the Travel Subroutine to compute the CTV's travel time and distance traveled to the next commercial collection unit to be collected on its route. The travel time and distance traveled are added to their respective totals for the CTV. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 12 for the CTV with a time of occurrence equal to the time on the Clock plus the travel time.

  If a train in the CTV's convoy is waiting to be dumped, CTSL calls the File Subroutine to enter into the Event Table an Event Type 15 for the CTV with a time of occurrence equal to the time on the Clock.
- Event Type 14--For an Event Type 14, CTSL determines whether or not the CTV involved is waiting for a call from a train when it receives the call. If the CTV was not waiting for a call, CTSL merely continues with the simulation. But, if the CTV was waiting for a call, CTSL determines for how long it has been waiting. The length of time waiting for a call is added to the CTV's total time waiting for a call. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 15 for the CTV with a time of occurrence equal to the time on the Clock.

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- Event Type 15--For Event Type 15, CTSL calls the Travel Subroutine to compute the CTV's travel time and distance traveled to the train to be dumped. The travel time and distance traveled are added to their respective totals for the CTV. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 16 for the CTV with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 16--For Event Type 16, CTSL removes the train to be dumped from its convoy's queue of trains waiting to be dumped and determines the length of time that it has been waiting. Then, CTSL calls the Collection Subroutine III to compute the amount of solid waste dumped from the train by the CTV in its convoy and the dump time. The performance statistics are added to their respective totals for the train and the CTV. Next, CTSL calls the File Subroutine to enter into the Event Table an event for the train. CTSL determines the type of event to be filed in accordance with the following rules:

    - If the train has not completed its collection route, file Event Type 2.

    - If the train has completed its collection route, file Event Type 4.

  CTSL determines the time of occurrence of the event to be filed in accordance with the following rules:

    - If the train is not involved in a prescheduled activity and is not broken down when it is dumped by the CTV, the time of occurrence is equal to the time on the Clock plus the dump time.

    - If the train is involved in a prescheduled activity or is broken down when it is dumped by the CTV, the time of occurrence is equal to the larger of the following two values:

        (1) The time when the train is scheduled to complete the prescheduled activity or return to service after the breakdown

        (2) The time on the Clock plus the dump time

  Finally, CTSL calls the File Subroutine to enter into the Event Table an event for the CTV with a time of occurrence equal to the time on the Clock plus the dump time. CTSL determines the type of the event to be filed in accordance with the following rules:

    - If the CTV is full, file Event Type 17.

    - If the CTV is not full and a train in its convoy is waiting to be dumped, file Event Type 15.

  - If the CTV is not full and there are not any trains in its convoy waiting to be dumped but it has not completed its commercial collection route, file Event Type 13.

  - If the CTV is not full and there are not any trains in its convoy waiting to be dumped but it has completed its commercial collection route and all the trains in its convoy have completed their collection routes, file Event Type 17.

  - If the CTV is not full and there are not any trains in its convoy waiting to be dumped and it has completed its commercial collection route but all the trains in its convoy have not completed their collection routes, file Event Type 10.

- Event Type 17--For Event Type 17, CTSL calls the Travel Subroutine to compute the CTV's travel time and distance traveled to its disposal site. The travel time and distance traveled are added to their respective totals for the CTV. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 18 for the CTV with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 18--For Event Type 18, CTSL determines whether or not the disposal site of the CTV involved has scales; and if it does, whether or not all of the scales are busy. If the CTV's disposal site has scales and all of them are busy, CTSL places the CTV in its disposal site's queue of collection vehicles waiting to use the scales. Otherwise, if not all of the scales of the CTV's disposal site are busy, CTSL calls the File Subroutine to enter into the Event Table an Event Type 19 for the CTV with a time of occurrence equal to the time on the Clock.

  If the CTV's disposal site does not have scales, CTSL calls the File Subroutine to enter into the Event Table an Event Type 20 for the CTV with a time of occurrence equal to the time on the Clock.

- Event Type 19--For an Event Type 19, CTSL calls the Weigh Subroutine to compute the length of time it takes for the CTV to be weighed on scales at its disposal site. The weighing time is added to the total weighing time for the CTV. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 20 for the CTV with a time of occurrence equal to the time on the Clock plus the weighing time.

- Event Type 20--For an Event Type 20, CTSL first determines whether or not there is another collection vehicle waiting to weigh at the disposal site of the CTV involved. If there is not, or if there are no scales at the CTV's disposal site, CTSL then determines whether or not all of the dumping channels at the CTV's disposal site are busy. If all of the dumping channels are busy, CTSL places the CTV in its disposal site's queue of collection vehicles waiting to use a dumping channel. Otherwise, if not all of the dumping channels are busy, calls the File Subroutine to enter into the Event Table an Event Type 21 for the CTV with a time of occurrence equal to the time on the Clock.

If there is another collection vehicle waiting to use the scales at the CTV's disposal site, CTSL removes the first collection vehicle from the disposal site's queue of collection vehicles waiting to use the scales and determines how long it has been waiting to use the scales. The waiting time is added to the total time waiting at scales for the collection vehicle. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 19 for the collection vehicle with a time of occurrence equal to the time on the Clock. Next, CTSL determines whether or not all of the dumping channels at the CTV's disposal site are busy and continues as in the case where there is not another collection vehicle waiting to use the scales at the CTV's disposal site.

- Event Type 21--For an Event Type 21, CTSL calls the Dump Subroutine to compute the length of time it takes the CTV involved to dump at its disposal site. The dump time is added to the CTV's total dump time. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 22 for the CTV with a time of occurrence equal to the Clock time plus the dump time.

- Event Type 22--For Event Type 22, CTSL first determines whether or not there is another collection vehicle waiting to dump at the CTV's disposal site. If there is not, CTSL then calls the File Subroutine to enter into the Event Table an event for the CTV with a time of occurrence equal to the time on the Clock. CTSL determines the type of the event to be filed in accordance with the following rules:

    - If a train in the CTV's convoy is waiting to be dumped, file Event Type 15.

    - If there are not any trains in the CTV's convoy waiting to be dumped and the CTV has not completed its commercial collection route, file an Event Type 13.

    - If there are not any trains in the CTV's convoy waiting to be dumped but the CTV has completed its commercial collection route and all the trains in its convoy have completed their collection routes, file an Event Type 23.

    - If there are not any trains in the CTV's convoy waiting to be dumped and the CTV has completed its commercial collection route but all trains in its convoy have not completed their collection routes, file an Event Type 10.

  If there is another collection vehicle waiting to dump at the CTV's disposal site, CTSL removes the first collection vehicle from the disposal site's queue of collection vehicles waiting to use a dumping channel and determines how long it has been waiting to dump. The waiting time is added to the total time waiting to dump for the collection vehicle. Then, CTSL calls the File Subroutine

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to enter into the Event Table an Event Type 21 for the collection vehicle with a time of occurrence equal to the time on the Clock. Next, CTSL calls the File Subroutine and continues as in the case where there is not another collection vehicle waiting to dump at the CTV's disposal site.

Finally, CTSL determines whether or not the CTV had a prescheduled activity postponed while it was at its disposal site, or traveling to it. If it did, CTSL calls the File Subroutine to enter into the Event Table an Event Type 25 for the CTV with a time of occurrence equal to the time on the Clock. If it did not, CTSL merely continues with the simulation.

- Event Type 23--For an Event Type 23, CTSL calls the Travel Subroutine to compute the CTV's travel time and distance traveled from its disposal site to its headquarters. The travel time and distance traveled are added to their respective totals for the CTV. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 24 for the CTV with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 24--Event Type 24 marks the arrival of the CTV involved back at its headquarters and the end of its collection day. Therefore, CTSL checks to see if there are any events left in the Event Table. If there is, CTSL removes the earliest event from the Event Table and continues with the simulation. If there is not, the collection system has completed its collection day, and CTSL transfers control to the input/output logic for generation of the input tape to the Output Program Module.

- Event Type 25--If the CTV involved is broken down when an Event Type 25 for it is removed from the Event Table, CTSL searches the Event Table to find the time when the CTV will return to service and calls the File Subroutine to enter into the Event Table an Event Type 25 for the CTV with a time of occurrence equal to the time when the CTV will return to service.

  If the CTV is not broken down, CTSL determines whether or not the CTV is waiting at its disposal site. If it is, CTSL postpones the prescheduled activity until the CTV has finished dumping at its disposal site. If the CTV is not waiting at its disposal site, CTSL determines whether or not the CTV is waiting for a call from a train. If it is waiting for a call, CTSL determines how long it has been waiting, and calls the Prescheduled Activities Subroutine II to determine the duration of the prescheduled activity and any distance traveled by the CTV during the prescheduled activity. These performance statistics are added to their respective totals for the CTV. Then, CTSL calls the File Subroutine to enter into the Event Table and Event Type 26 for the CTV with a time of occurrence equal to the time on the Clock plus the duration of the prescheduled activity.

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If the CTV is not waiting for a call from a train, CTSL searches the Event Table to find the CTV's next event which is other than a "receipt of a call" event (Event Type 14) and a "breakdown" event (Event Type 27). If the CTV does not have such a next event, its collection day is over and CTSL cancels the prescheduled activity. If the CTV's next event is one where the CTV is at its disposal site or traveling to it (Event Type 18, 19, 20, 21, or 22), CTSL postpones the prescheduled activity until the CTV has finished dumping at its disposal site. Otherwise, CTSL calls the Remove Subroutine to remove the CTV's next event from the Event Table, and calls the Prescheduled Activities Subroutine II to determine the duration of the prescheduled activity and any distance traveled by the CTV during the prescheduled activity. These performance statistics are added to their respective totals for the CTV. Then, CTSL calls the File Subroutine to enter the following events into the Event Table:

- The next event type for the CTV with a time of occurrence equal to either (1) the time of occurrence of the CTV's next event plus the duration of the prescheduled activity, or (2) if the CTV's next event type is an Event Type 11, the time on the Clock plus the duration of the prescheduled activity.

- An Event Type 26 for the CTV with a time of occurrence equal to the time on the Clock plus the duration of the prescheduled activity

- Event Type 26--For an Event Type 26, CTSL first determines whether or not the CTV involved in the prescheduled activity just completed was waiting for a call from a train when it started the prescheduled activity. If the CTV was not waiting for a call, CTSL calls the Prescheduled Activities Subroutine III to determine (1) whether or not the CTV has another prescheduled activity, and (2) if it does, the time of occurrence of its next prescheduled activity. If the Prescheduled Activities Subroutine III determines that the CTV does have another prescheduled activity, CTSL calls the File Subroutine to enter into the Event Table an Event Type 25 for the CTV with a time of occurrence equal to that determined by the Prescheduled Activities Subroutine III. If the Prescheduled Activities Subroutine III determines that the CTV does not have another prescheduled activity, CTSL merely continues with the simulation.

  If the CTV was waiting for a call from a train, CTSL calls the File Subroutine to enter into the Event Table an event for the CTV with a time of occurrence equal to the time on the Clock. CTSL determines the type of the event to be filed in accordance with the following rules:

  - If the CTV did receive a call from a train during the prescheduled activity, file Event Type 15.

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- If the CTV did not receive a call from a train during the prescheduled activity, file Event Type 10.

Next, CTSL calls the Prescheduled Activities Subroutine III and continues as in the case where the CTV had not been waiting for a call from a train.

- Event Type 27--For an Event Type 27, CTSL calls the Breakdown Subroutine II to determine how long the CTV involved will be broken down. CTSL compares the down time to the specified replacement time (maximum allowable down time before replacement), and if the down time is greater than the replacement time, the CTV is replaced and the down time is set equal to the replacement time. Next, CTSL determines whether or not the CTV is waiting either at its disposal site or for a call from a train. If it is waiting, CTSL removes it from the queue and/or computes the length of time that it has been waiting. The time waiting and the down time are added to their respective totals for the CTV. Then, CTSL calls the File Subroutine to enter into the Event Table an Event Type 28 for the CTV with a time of occurrence equal to the time on the Clock plus the down time.

  If the CTV is not waiting, CTSL searches the Event Table to find the CTV's next event other than a "receipt of a call" event (Event Type 14) and the start of a prescheduled activity (Event Type 25). If the next event found for the CTV is an Event Type 26, CTSL calls the Remove Subroutine to remove it from the Event Table, and then calls the File Subroutine to put the Event Type 26 for the CTV back into the Event Table with a time of occurrence equal to its previous time of occurrence plus the down time. CTSL continues to search the Event Table until it finds a next event for the CTV which is not an Event Type 14 or an Event Type 25 or an Event Type 26. If the CTV does not have such a next event, its collection day is over and CTSL cancels the breakdown. Otherwise, when it finds such a next event, CTSL calls the Remove Subroutine to remove it from the Event Table. The down time is added to the total down time for the CTV. Then, CTSL calls the File Subroutine to enter the following events into the Event Table:

  - The next event for the CTV with a time of occurrence equal to the time of occurrence of the CTV's next event plus the down time
  - An Event Type 28 for the CTV with a time of occurrence equal to the time on the Clock plus the down time

- Event Type 28--For an Event Type 28, CTSL first determines whether or not the CTV involved was waiting either at its disposal site or for a call from a train when it broke down. If the CTV was not waiting, CTSL calls the Breakdown Subroutine III to determine (1) whether or not the CTV is to have another breakdown, and (2) if it is, the time of occurrence of its next breakdown. If the

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Breakdown Subroutine III determines that the CTV does have another breakdown, CTSL calls the File Subroutine to enter into the Event Table an Event Type 27 for the CTV with a time of occurrence equal to that determined by the Breakdown Subroutine III. If the Breakdown Subroutine III determines that the CTV does not have another breakdown, CTSL merely continues with the simulation.

If the CTV was waiting in the queue waiting to weigh at its disposal site, CTSL calls the File Subroutine to enter into the Event Table an Event Type 18 for the CTV with a time of occurrence equal to the time on the Clock. Then, CTSL calls the Breakdown Subroutine III and continues as in the case where the CTV had not been waiting.

If the CTV was waiting in the queue waiting to dump at its disposal site, CTSL determines whether or not all of the dumping channels at the CTV's disposal site are busy. If all of the dumping channels are busy, CTSL places the CTV in its disposal site's queue of collection vehicles waiting to dump. Otherwise, if not all of the dumping channels are busy, CTSL calls the File Subroutine to enter into the Event Table an Event Type 21 for the CTV with a time of occurrence equal to the time on the Clock. Then, CTSL calls the Breakdown Subroutine III and continues as in the case where the CTV had not been waiting.

If the CTV was waiting for a call from a train, CTSL calls the File Subroutine to enter into the Event Table an event for the CTV with a time of occurrence equal to the time on the Clock. CTSL determines the type of the event to be filed in accordance with the following rules:

- If the CTV did receive a call from a train during the breakdown, file Event Type 15.
- If the CTV did not receive a call from a train during the breakdown, file Event Type 10.

Then, CTSL calls the Breakdown Subroutine III and continues as in the case where the CTV had not been waiting.

Other Residential Collection System Logic. The other residential collection system logic (ORCSL) uses the operational sequence shown in Figure 11 for ordering the occurrence of system events, which are presented in Table 2. A discussion of ORCSL in terms of these system events follows.

- Event Type 31--For an Event Type 31, ORCSL calls the Travel Subroutine to compute (1) the length of time it takes the collection vehicle (CV) involved to travel from its headquarters to its collection route, and (2) the distance it travels. The travel time is added to the CV's total travel time and the distance traveled is added to the CV's total distance traveled. Then,

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TABLE 2. SYSTEM EVENTS FOR A PACKER-TRUCK, ALLEY/STREET-CONTAINER, OR MECHANICAL-BAG-RETRIEVER SYSTEM

EVENT TYPE	DESCRIPTION
31	*CV leaves headquarters for collection route.
32	CV starts to collect.
33	CV starts to travel to disposal site.
34	CV arrives at disposal site.
35	CV starts to weigh at disposal site.
36	CV finishes weighing at disposal site.
37	CV starts to dump at disposal site.
38	CV finishes dumping at disposal site.
39	CV starts to travel to collection route from disposal site.
40	CV returns to headquarters from disposal site.
41	CV arrives at headquarters.
42	CV starts a prescheduled activity.
43	CV completes a prescheduled activity.
44	CV breaks down.
45	CV returns to service after a breakdown.

*CV - collection vehicle

ORCSL calls the File Subroutine to enter into the Event Table an Event Type 32 for the CV with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 32--For an Event Type 32, ORCSL calls the Collection Subroutine I to determine the following performance statistics for the CV involved:

  - Amount of solid waste collected
  - Collection time
  - Collection distance
  - Non-collection time
  - Non-collection distance
  - Number of residential units served
  - Floor area of residential units served
  - Number of persons in residential units served
  - Income of residential units served
  - Number of carry-outs by type

  These statistics are added to their respective totals for the CV. Then, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 33 for the CV with a time of occurrence equal to the time on the Clock plus the collection and non-collection times.

- Event Type 33--For an Event Type 33, ORCSL calls the Travel Subroutine to compute the CV's travel time and distance traveled to its disposal site. The travel time and distance traveled are added to their respective totals for the CV. Then, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 34 for the CV with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 34--For an Event Type 34, ORCSL determines whether or not the disposal site of the CV involved has scales; and if it does, whether or not all of the scales are busy. If the CV's disposal site has scales and all of them are busy, ORCSL places the CV in its disposal site's queue of collection vehicles waiting to use the scales. Otherwise, if not all of the scales at the CV's disposal site are busy, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 35 for the CV with a time of occurrence equal to the time on the Clock.

  If the CV's disposal site does not have scales, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 36 for the CV with a time of occurrence equal to the time on the Clock.

- Event Type 35--For an Event Type 35, ORCSL calls the Weigh Subroutine to compute the length of time it takes for the CV involved to be weighed on scales at its disposal site. The weighing time is added to the total weighing time for the CV. Then,

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ORCSL calls the File Subroutine to enter into the Event Table an Event Type 36 for the CV with a time of occurrence equal to the time of the Clock plus the weighing time.

- Event Type 36--For an Event Type 36, ORCSL first determines whether or not there is another collection vehicle waiting to weigh at the disposal site of the CV involved. If there is not, or if there are no scales at the CV's disposal site, ORCSL then determines whether or not all of the dumping channels at the CV's disposal site are busy. If all of the dumping channels are busy, ORCSL places the CV in its disposal site's queue of collection vehicles waiting to use a dumping channel. Otherwise, if not all of the dumping channels are busy, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 37 for the CV with a time of occurrence equal to the time on the Clock.

  If there is another collection vehicle waiting to use the scales at the CV's disposal site, ORCSL removes the first collection vehicle from the disposal site's queue of collection vehicles waiting to use the scales and determines how long it has been waiting to use the scales. The waiting time is added to its total time waiting at scales. Then, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 35 for the collection vehicle with a time of occurrence equal to the time on the Clock. Next, ORCSL determines whether or not all of the dumping channels at the CV's disposal site are busy and continues as in the case when there is not another collection vehicle waiting to use the scales at the CV's disposal site.

- Event Type 37--For an Event Type 37, ORCSL calls the Dump Subroutine to compute the length of time it takes the CV involved to dump at its disposal site. The dump time is added to the CV's total dump time. Then, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 38 for the CV with a time of occurrence equal to the time on the Clock plus the dump time.

- Event Type 38--For an Event Type 38, ORCSL first determines whether or not there is another collection vehicle waiting to dump at the CV's disposal site. If there is not, ORCSL then calls the File Subroutine to enter into the Event Table an event for the CV with a time of occurrence equal to the time on the Clock. ORCSL determines the type of the event to be filed in accordance with the following rules:

  - If the CV has not completed its collection route, file Event Type 39.

  - If the CV has completed its collection route, file Event Type 40.

  If there is another collection vehicle waiting to dump at the CV's disposal site, ORCSL removes the first collection vehicle from the disposal site's queue of collection vehicles waiting to use a dumping channel and determines how long it has been waiting to dump. The waiting time is added to the total time waiting to dump for the collection vehicle. Then, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 37 for the collection vehicle with a time of occurrence equal to the time on the Clock. Next, ORCSL calls the File Subroutine and continues as in the case where there is not another collection vehicle waiting to dump at the CV's disposal site.

Finally, ORCSL determines whether or not the CV had a prescheduled activity postponed while it was at its disposal site or traveling to it. If it did, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 42 for the CV with a time of occurrence equal to the time on the Clock. If it did not, ORCSL merely continues with the simulation.

- Event Type 39--For an Event Type 39, ORCSL calls the Travel Subroutine to compute the CV's travel time and distance traveled from its disposal site to its collection route. The travel time and distance traveled are added to their respective totals for the CV. Then, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 32 for the CV with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 40--For an Event Type 40, ORCSL calls the Travel Subroutine to compute the CV's travel time and distance traveled from its disposal site to its headquarters. The travel time and distance traveled are added to their respective totals for the CV. Then, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 41 for the CV with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 41--Event Type 41 marks the arrival of the CV involved back at its headquarters and the end of its collection day. Therefore, ORCSL checks to see if there are any events left in the Event Table. If there is, ORCSL removes the earliest event from the Event Table and continues with the simulation. If there is not, the collection system has completed its collection day, and ORCSL transfers control to the input/output logic for generation of the input tape to the Output Program Module.

- Event Type 42--If the CV involved is broken down when Event Type 42 for it is removed from the Event Table, ORCSL searches the Event Table to find the time when the CV will return to service and calls the File Subroutine to enter into the Event Table an Event Type 42 for the CV with a time of occurrence equal to the time when the CV will return to service.

  If the CV is not broken down, ORCSL determines whether or not the CV is waiting at its disposal site. If it is, ORCSL postpones the prescheduled activity until the CV has finished

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dumping at its disposal site. If the CV is not waiting at its disposal site, ORCSL searches the Event Table to find the CV's next event which is other than a "breakdown" event (Event Type 44). If the CV does not have such a next event, its collection day is over and ORCSL cancels the prescheduled activity. If the CV's next event is one where the CV is at its disposal site or traveling to it (Event Type 34, 35, 36, 37, or 38), ORCSL postpones the prescheduled activity until the CV has finished dumping at its disposal site. Otherwise, ORCSL calls the Remove Subroutine to remove the CV's next event from the Event Table, and calls the Prescheduled Activities Subroutine II to determine the duration of the prescheduled activity and any distance traveled by the CV during the prescheduled activity. These performance statistics are added to their respective totals for the CV. Then, ORCSL calls the File Subroutine to enter the following events into the Event Table:

  - The next event type for the CV with a time of occurrence equal to either (1) the time of occurrence of the CV's next event plus the duration of the prescheduled activity, or (2) if the CV's next event type is an Event Type 31, the time on the Clock plus the duration of the prescheduled activity.
  - An Event Type 43 for the CV with a time of occurrence equal to the time on the Clock plus the duration of the prescheduled activity.

- Event Type 43--For an Event Type 43, ORCSL calls the Prescheduled Activities Subroutine III to determine (1) whether or not the CV has another preshceduled activity, and (2) if it does, the time of occurrence of its next prescheduled activity. If the Prescheduled Activities Subroutine III determines that the CV does have another prescheduled activity, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 42 for the CV with a time of occurrence equal to that determined by the Prescheduled Activities Subroutine III. If the Prescheduled Activities Subroutine III determines that the CV does not have another prescheduled activity, ORCSL merely continues with the simulation.

- Event Type 44--For an Event Type 44, ORCSL calls the Breakdown Subroutine II to determine how long the CV involved will be broken down. ORCSL compares the down time to the specified replacement time (maximum allowable down time before replacement), and if the down time is greater than the replacement time, the CV is replaced and the down time is set equal to the replacement time. Next, ORCSL determines whether or not the CV is waiting at its disposal site. If it is waiting, ORCSL removes it from the queue and computes the length of time that it has been waiting. The time waiting and the down time are added to their respective totals for the CV. Then, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 45 for the CV with a time of occurrence equal to the time on the Clock plus the down time.

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If the CV is not waiting at its disposal site, ORCSL searches the Event Table to find the CV's next event other than the start of a prescheduled activity (Event Type 42). If the next event found for the CV is an Event Type 43, ORCSL calls the Remove Subroutine to remove it from the Event Table, and then calls the File Subroutine to put the Event Type 43 for the CV back into the Event Table with a time of occurrence equal to its previous time of occurrence plus the down time. ORCSL continues to search the Event Table until it finds a next event for the CV which is not an Event Type 42 or an Event Type 43. If the CV does not have such a next event, its collection day is over and ORCSL cancels the breakdown. Otherwise, when it finds such a next event, ORCSL calls the Remove Subroutine to remove it from the Event Table. The down time is added to the total down time for the CV. Then, ORCSL calls the File Subroutine to enter the following events into the Event Table:

- The next event for the CV with a time of occurrence equal to the time of occurrence of the CV's next event plus the down time
- An Event Type 45 for the CV with a time occurrence equal to the time on the Clock, plus the down time

- Event Type 45--For an Event Type 45, ORCSL first determines whether or not the CV involved was waiting at its disposal site when it broke down. If the CV was not waiting, ORCSL calls the Breakdown Subroutine III to determine (1) whether or not the CV is to have another breakdown, and (2) if it is , the time of occurrence of its next breakdown. If the Breakdown Subroutine III determines that the CV does have another breakdown, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 44 for the CV with a time of occurrence equal to that determined by the Breakdown Subroutine III. If the Breakdown Subroutine III determines that the CV does not have another breakdown, ORCSL merely continues with the simulation.

  If the CV was waiting in the queue waiting to weigh at its disposal site, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 34 for the CV with a time of occurrence equal to the time on the Clock. Then, ORCSL calls the Breakdown Subroutine III and continues as in the case where the CV had not been waiting.

  If the CV was waiting the queue waiting to dump at its disposal site, ORCSL determines whether or not all of the dumping channels at the CV's disposal site are busy. If all of the dumping channels are busy, ORCSL places the CV in its disposal site's queue of collection vehicles waiting to dump. Otherwise, if not all of the dumping channels are busy, ORCSL calls the File Subroutine to enter into the Event Table an Event Type 37 for the CV with a time of occurrence equal to the time on the Clock. Then, ORCSL calls the Breakdown Subroutine III and continues as in the case where the CV had not been waiting.

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Commercial Collection System Logic. The commerical collection system logic (CCSL), uses the operational sequence shown in Figure 14 for ordering the occurrence of system events, which are presented in Table 3. A discussion of CCSL in terms of these events follows.

- Event Type 46--For an Event Type 46, CCSL calls the Travel Subroutine to compute (1) the length of time it takes the commercial collection vehicle (CCV) involved to travel from its headquarters to its collection route, and (2) the distance it travels. The travel time is added to the CCV's total travel time and the distance traveled is added to the CCV's total distance traveled. Then, CCSL calls the File Subroutine to enter into the Event Table an Event Type 47 for the CCV with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 47--For an Event Type 47, CCSL calls the Collection Subroutine II to determine (1) the amount of solid waste collected, (2) the collection time, and (3) the number of fixed containers dumped. These performance statistics are added to their respective totals for the CCV involved. Then, CCSL calls the File Subroutine to enter into the Event Table an event for the CCV with a time of occurrence equal to the time on the Clock plus the collection time. CCSL determines the type of the event to be filed in accordance with the following rules:

    - If the CCV is full, file Event Type 49.

    - If the CCV is not full but has completed its collection route, file Event Type 49.

    - If the CCV is not full and has not completed its collection route, file Event Type 48.

- Event Type 48--For an Event Type 48, CCSL calls the Travel Subroutine to compute the CCV's travel time and distance traveled to the next commercial collection unit to be collected on its route. The travel time and distance traveled are added to their respective totals for the CCV. Then, CCSL calls the File Subroutine to enter into the Event Table an Event Type 47 for the CCV with a time of occurrence equl to the time on the Clock plus the travel time.

- Event Type 49--For an Event Type 49, CCSL calls the Travel Subroutine to compute the CCV's travel time and distance traveled to its disposal site. The travel time and distance traveled are added to their respective totals for the CCV. Then, CCSL calls the File Subroutine to enter into the Event Table an Event Type 50 for the CCV with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 50--For an Event Type 50, CCSL determines whether or not the disposal site of the CCV involved has scales, and if it does, whether or not all of the scales are busy. If the CCV's disposal

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TABLE 3. SYSTEM EVENTS FOR A COMMERCIAL COLLECTION SYSTEM

EVENT TYPE	DESCRIPTION
46	*CCV leaves headquarters for collection route.
47	CCV starts to collect a commercial collection unit.
48	CCV starts to travel to a commercial collection unit.
49	CCV starts to travel to disposal site.
50	CCV arrives at disposal site.
51	CCV starts to weigh at disposal site.
52	CCV finishes weighing at disposal site.
53	CCV starts to dump at disposal site.
54	CCV finishes dumping at disposal site.
55	CCV returns to headquarters from disposal site.
56	CCV arrives at headquarters.
57	CCV starts a prescheduled activity.
58	CCV completes a prescheduled activity.
59	CCV breaks down.
60	CCV returns to service after a breakdown.

*CCV - commercial collection vehicle

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site has scales and all of them are busy, CCSL places the CCV in its disposal site's queue of collection vehicles waiting to use the scales. Otherwise, if not all of the scales at the CCV's disposal site are busy, CCSL calls the File Subroutine to enter into the Event Table an Event Type 51 for the CCV with a time of occurrence equal to the time on the Clock.

If the CCV's disposal site does not have scales, CCSL calls the File Subroutine to enter into the Event Table an Event Type 52 for the CCV with a time of occurrence equal to the time on the Clock.

- Event Type 51--For an Event Type 51, CCSL calls the Weigh Subroutine to compute the length of time it takes for the CCV involved to be weighed on scales at its disposal site. The weighing time is added to the total weighing time for the CCV. Then, CCSL calls the File Subroutine to enter into the Event Table an Event Type 52 for the CCV with a time of occurrence equal to the time on the Clock plus the weighing time.

- Event Type 52--For an Event Type 52, CCSL first determines whether or not there is another collection vehicle waiting to weigh at the disposal site of the CCV involved. If there is not, or if there are no scales at the CCV's disposal site, CCSL then determines whether or not all of the dumping channels at the CCV's disposal site are busy. If all of the dumping channels are busy, CCSL places the CCV in its disposal site's queue of collection vehicles waiting to use a dumping channel. Otherwise, if not all of the dumping channels are busy, CCSL calls the File Subroutine to enter into the Event Table an Event Type 53 for the CCV with a time of occurrence equal to the time on the Clock.

  If there is another collection vehicle waiting to use the scales at the CCV's disposal site, CCSL removes the first collection vehicle from the disposal site's queue of collection vehicles waiting to use the scales and determines how long it has been waiting to use the scales. The waiting time is added to its total time waiting at the scales. Then, CCSL calls the File Subroutine to enter into the Event Table an Event Type 51 for the collection vehicle with a time of occurrence equal to the time on the Clock. Next, CCSL determines whether or not all of the dumping channels at the CCV's disposal site are busy and continues as in the case where there is not another collection vehicle waiting to use the scales at the CCV's disposal site.

- Event Type 53--For an Event Type 53, CCSL calls the Dump Subroutine to compute the length of time it takes the CCV involved to dump at its disposal site. The dump time is added to the CCV's total dump time. Then, CCSL calls the File Subroutine to enter into the Event Table an Event Type 54 for the CCV with a time of occurrence equal to the time on the Clock plus the dump time.

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- Event Type 54--For an Event Type 54, CCSL first determines whether or not there is another collection vehicle waiting to dump at the CCV's disposal site. If there is not, CCSL then calls the File Subroutine to enter into the Event Table an event for the CCV with a time of occurrence equal to the time on the Clock. CCSL determines the type of the event to be filed in accordance with the following rules:

  - If the CCV has not completed its collection route, file Event Type 48.

  - If the CCV has completed its collection route, file Event Type 55.

  If there is another collection vehicle waiting to dump at the CCV's disposal site, CCSL removes the first collection vehicle from the disposal site's queue of collection vehicles waiting to use a dumping channel and determines how long it has been waiting to dump. The waiting time is added to the total time waiting to dump for the collection vehicle. Then, CCSL calls the File Subroutine to enter into the Event Table an Event Type 53 for the collection vehicle with a time of occurrence equal to the time on the Clock. Next, CCSL calls the File Subroutine and continues as in the case where there is not another collection vehicle waiting to dump at the CCV's disposal site.

  Finally, CCSL determines whether or not the CCV had a prescheduled activity postponed while it was at its disposal site or traveling to it. If it did, CCSL calls the File Subroutine to enter into the Event Table an Event Type 57 for the CCV with a time of occurrence equal to the time on the Clock. If it did not, CCSL merely continues with the simulation.

- Event Type 55--For an Event Type 55, CCSL calls the Travel Subroutine to compute the CCV's travel time and distance traveled from its disposal site to its headquarters. The travel time and distance traveled are added to their respective totals for the CCV. Then, CCSL calls the File Subroutine to enter into the Event Table an Event Type 56 for the CCV with a time of occurrence equal to the time on the Clock plus the travel time.

- Event Type 56--Event Type 56 marks the arrival of the CCV involved back at its headquarters and the end of its collection day. Therefore, CCSL checks to see if there are any events left in the Event Table. If there is, CCSL removes the earliest event from the Event Table and continues with the simulation. If there is not, the collection system has completed its collection day, and CCSL transfers control to the input/output logic for generation of the input tape to the Output Program Module.

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- Event Type 57--If the CCV involved is broken down when Event Type 57 for it is removed from the Event Table, CCSL searches the Event Table to find the time when the CCV will return to service and calls the File Subroutine to enter into the Event Table an Event Type 57 for the CCV with a time of occurrence equal to the time when the CCV will return to service.

  If the CCV is not broken down, CCSL determines whether or not the CCV is waiting at its disposal site. If it is, CCSL postpones the prescheduled activity until the CCV has finished dumping at its disposal site. If the CCV is not waiting at its disposal site, CCSL searches the Event Table to find CCV's next event which is other than a "breakdown" event (Event Type 59). If the CCV does not have such a next event, its collection day is over and CCSL cancels the prescheduled activity. If the CCV's next event is one where the CCV is at its disposal site or traveling to it (Event Type 50, 51, 52, 53, and 54), CCSL postpones the prescheduled activity until the CCV has finished dumping at its disposal site. Otherwise, CCSL calls the Remove Subroutine to remove the CV's next event from the Event Table, and calls the Prescheduled Activities Subroutine II to determine the duration of the prescheduled activity and any distance traveled by the CCV during the prescheduled activity. These performance statistics are added to their respective totals for the CCV. Then, CCSL calls the File Subroutine to enter the following events into the Event Table:

  - The next event type for the CCV with a time of occurrence equal to either (1) the time of occurrence of the CCV's next event plus the duration of the prescheduled activity, or (2) if the CCV's next event type is an Event Type 46, the time on the Clock plus the duration of the prescheduled activity

  - An Event Type 58 for the CCV with a time of occurrence equal to the time on the Clock plus the duration of the prescheduled activity

- Event Type 58--For an Event Type 58, CCSL calls the Prescheduled Activities Subroutine III to determine (1) whether or not the CCV has another prescheduled activity, and (2) if it does, the time of occurrence of its next prescheduled activity. If the Prescheduled Activities Subroutine III determines that the CCV does have another prescheduled activity, CCSL calls the File Subroutine to enter into the Event Table an Event Type 57 for the CCV with a time of occurence equal to that determined by the Prescheduled Activities Subroutine III. If the Prescheduled Activities Subroutine III determines that the CV does not have another prescheduled activity, CCSL merely continues with the simulation.

- Event Type 59--For an Event Type 59, CCSL calls the Breakdown Subroutine II to determine how long the CCV involved will be broken down. CCSL compares the down time to the specified replacement time (maximum allowable down time before replacement), and if the down time is greater than the replacement time, the CCV is replaced and the down time is set equal to the replacement time. Next, CCSL determines whether or not the CCV is waiting at its disposal site. If it is waiting, CCSL removes it from the queue and computes the length of time that it has been waiting. The time waiting and the down time are added to their respective totals for the CCV. Then, CCSL calls the File Subroutine to enter into the Event Table an Event Type 60 for the CCV with a time of occurrence equal to the time on the Clock plus the down time.

If the CCV is not waiting at its disposal site, CCSL searches the Event Table to find the CCV's next event other than the start of a prescheduled activity (Event Type 57). If the next event found for the CCV is an Event Type 58, CCSL calls the Remove Subroutine to remove it from the Event Table, and then calls the File Subroutine to put the Event Type 58 for the CCV back into the Event Table with a time of occurrence equal to its previous time of occurrence plus the down time. CCSL continues to search the Event Table until it finds a next event for the CCV which is not an Event Type 57 or an Event Type 58. If the CCV does not have such a next event, its collection day is over and CCSL cancels the breakdown. Otherwise, when it finds such a next event, CCSL calls the Remove Subroutine to remove it from the Event Table. The down time is added to the total down time for the CCV. Then, CCSL calls the File Subroutine to enter the following events into the Event Table:

- The next event for the CCV with a time of occurrence equal to the time of occurrence of the CCV's next event plus the down time
- An Event Type 60 for the CCV with a time of occurrence equal to the time on the Clock plus the down time

- Event Type 60--For an Event Type 60, CCSL first determines whether or not the CCV involved was waiting at its disposal site when it broke down. If the CCV was not waiting, CCSL calls the Breakdown Subroutine III to determine (1) whether or not the CCV is to have another breakdown, and (2) if it is, the time of occurrence of its next breakdown. If the Breakdown Subroutine III determines that the CCV does have another breakdown, CCSL calls the File Subroutine to enter into the Event Table an Event Type 59 for the CCV with a time of occurrence equal to that determined by the Breakdown Subroutine III. If the Breakdown Subroutine III determines that the CCV does not have another breakdown, CCSL merely continues with the simulation.

  If the CCV was waiting in the queue waiting to weigh at its disposal site, CCSL calls the File Subroutine to enter into the Event Table an Event Type 50 for the CCV with a time of occurrence equal to the time on the Clock. Then, CCSL calls the Breakdown Subroutine III and continues as in the case where the CCV had not been waiting.

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If the CCV was waiting in the queue waiting to dump at its disposal site, CCSL determines whether or not all of the dumping channels at the CCV's disposal site are busy. If all of the dumping channels are busy, CCSL places the CCV in its disposal site's queue of collection vehicles waiting to dump. Otherwise, if not all of the dumping channels are busy, CCSL calls the File Subroutine to enter into the Event Table an Event Type 53 for the CCV with a time of occurrence equal to the time on the Clock. Then, CCSL calls the Breakdown Subroutine III and continues as in the case where the CCV had not been waiting.

CHAPTER VI

ACTIVITY SUBPROGRAMS

ACTIVITY SUBPROGRAMS

FUNCTION

Activity Subprograms are called by the Main Program to compute the durations of activities in the operation of the collection system being simulated and determine the performances of the collection vehicles involved. The subroutines which comprise the set of Activity Subprograms and their functions are the following:

- Departure Subroutine--Called to determine and file in the Event Table the time at which each collection vehicle will leave its headquarters to start its collection day.

- Travel Subroutine--Called to compute the length of time it will take a collection vehicle to travel from one place to another and the distance traveled.

- Collection Subroutine I--Called to determine the length of time it will take a residential collection vehicle to collect solid waste along its collection route until it either becomes full or it completes its collection route. It also determines the distance traveled; the amount of solid waste collected; the number, floor area, number of persons, and income of the residential units served; and the number of carry-outs by type.

- Collection Subroutine II--Called to determine the length of time it takes a collection vehicle to collect solid waste from a commercial collection unit. It also determines the amount of solid waste collected and the number of fixed-containers dumped.

- Collection Subroutine III--Called to determine the length of time it takes a container transfer vehicle to dump a container train.

- Weigh Subroutine--Called to determine the length of time it takes a collection vehicle to weigh on the scales at its disposal site.

- Dump Subroutine--Called to determine the length of time it takes a collection vehicle to dump at its disposal site, and the amount of solid waste dumped.

- Prescheduled Activities Subroutine I--Called to determine and file in the Event Table the time of occurrence of the first prescheduled activity of each collection vehicle that has at least one prescheduled activity.

- Prescheduled Activities Subroutine II--Called to determine the duration of a prescheduled activity and the distance traveled by the collection vehicle involved during the prescheduled activity.

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- Prescheduled Activities Subroutine III--Called to determine the time of occurrence of a collection vehicle's next prescheduled activity.
- Breakdown Subroutine I--Called to determine the number of breakdowns to occur for each collection vehicle during the collection day, and to determine and file in the Event Table the time of occurrence of the first breakdown of each collection vehicle that has at least one breakdown.
- Breakdown Subroutine II--Called to determine the down time and the replacement time for a collection vehicle that has broken down.
- Breakdown Subroutine III--Called to determine the time of occurrence of a collection vehicle's next breakdown.

LOGIC

The logic for the Activity Subprograms is illustrated by the flow charts in Appendix V. A discussion of the logic of each of these subprograms follows.

It should be noted that random variates used in the Activity Subprograms are drawn from probability distributions that are expressed in the form of cumulative histograms. The specific histograms that are programmed as part of the Activity Subprograms are presented in Appendix I. These histograms are used in a simulation run unless other cumulative histograms are input as optional performance characteristics and/or optional solid waste generation rates. (Refer to Chapter III for a discussion of these optional data sets.)

Departure Subroutine

The Departure Subroutine determines for each collection vehicle in the collection system the time at which it will leave its headquarters to start its collection day, and files its departure in the Event Table. The logic of the Departure Subroutine is illustrated by the flow chart in Figure V-1 in Appendix V.

When called by the Main Program, the Departure Subroutine first determines whether or not the departure times are to be assigned. If they are to be assigned, for each collection vehicle, the Departure Subroutine calls the File Subroutine to enter into the Event Table a departure event with a time of occurrence which has been read from the input tape by the input/output logic of the Main Program.

If the departure times are not to be assigned, for each collection vehicle, the Departure Subroutine draws a departure time at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of departure times for the headquarters and type of collection vehicle involved. Then, the Departure Subroutine calls the File Subroutine to enter into the Event Table the appropriate departure event for the collection vehicle with a time of occurrence equal to the departure time drawn.

Travel Subroutine

The Travel Subroutine determines the length of time it will take a collection vehicle to travel from one place to another and the distance traveled. The logic of the Travel Subroutine is illustrated by the flow chart in Figure V-2 in Appendix V.

When called by the Main Program, the Travel Subroutine first determines the distance to be traveled by the collection vehicle involved. The following procedure is used to estimate the distance traveled:

- If the trip is between nodes which are in the same street network area (an area within which the travel distance from any point to any other point can be considered to be equal to the "Metric L" distance between the two points), the "Metric L" distance between the two nodes is computed and used as the actual distance traveled.
- If the trip is between nodes which are not in the same street network area, the "Metric L" distance is computed between the origin node and the node at which the specified route to be traveled between the two street network areas intersects the boundary of the street network area that contains the trip's origin. And, the "Metric L" distance is computed between the destination node and the node at which the specified route to be traveled between the two street network areas intersects the boundary of the street network area that contains the trip's destination. The sum of these two "Metric L" distances and the predetermined distance traveled on the specified route between the two street network areas is used as the actual distance traveled.

Next, the Travel Subroutine draws a travel speed for the collection vehicle at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of travel speeds for the type of collection vehicle and distance involved. Then, the Travel Subroutine computes the travel time by dividing the distance traveled by the travel speed.

Collection Subroutine I

The Collection Subroutine I determines the length of time it takes a collection vehicle of a residential collection system to collect solid waste along its collection route, until either it becomes full or it completes its collection route. It also determines the following performance statistics:

- Amount of solid waste collected
- Collection time
- Collection distance
- Non-collection time
- Non-collection distance

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- Number of residential units served
- Floor area of residential units served
- Number of persons in residential units served
- Income of residential units served
- Number of carry-outs by type

The logic of the Collection Subroutine I is illustrated by the flow chart in Figure V-3 in Appendix V.

When called by the Main Program, the Collection Subroutine I finds the first link on the collection route of the collection vehicle involved which has not yet been collected. After it locates the first uncollected link, it determines whether or not the link is a collection link. If the link is not a collection link, the Collection Subroutine I computes the travel time on it and adds the travel time to the cumulative non-collection time for the load. It adds the length of the link to the cumulative non-collection distance for the load. Then, if the link is the last link on the collection vehicle's collection route, the Collection Subroutine I transfers control to the Main Program; otherwise, it considers the next link.

If the link is a collection link, the Collection Subroutine I computes the amount of solid waste to be collected and the collection time on it, and adds them to their respective cumulative totals for the load. The Collection Subroutine I also determines the values for the other performance statistics for the link and adds these to their respective cumulative totals for the load. Then, if the amount of solid waste collected fills the collection vehicle, or if the link is the last link on the collection vehicle's collection route, the Collection Subroutine I transfers control to the Main Program; otherwise, it repeats the procedure for the next link on the collection route.

The length of time it takes the collection vehicle to collect a load of solid waste is equal to the sum of the collection and non-collection times. The Collection Subroutine I computes the non-collection time for a non-collection link by dividing the length of the link by the speed of the collection vehicle, which it draws at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of collection vehicle speeds for the type of collection vehicle, distance, and link surface (paved or unpaved) involved.

The Collection Subroutine I computes the collection time for a collection link as the sum of the non-collection time on the link plus an average collection time per residential unit times the number of residential units on the link, plus an average additional collection time per carry-out times the number of carry-outs on the link. It computes the non-collection time in the same way that it computes the non-collection time for a non-collection link. It draws the average collection time per residential unit at random from a probability distribution expressed in the form of cumulative histogram that describes the occurrence of average collection times per residential unit for the type of collection vehicle, crew size, type of container (can or bag), link code (street/alley, one-side/two-side), link surface, and number of days since last collection involved. Likewise, it draws the average additional collection time per carry-out at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of average additional collection times per carry-out for the type of collection vehicle, crew size, type of container, link code, number of days since last collection, and type of carry-out involved.

The Collection Subroutine I computes the amount of solid waste collected on a collection link by multiplying the number of residential units on the link by an average amount of solid waste generated per residential unit. It draws the average amount of solid waste generated per residential unit at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of solid waste generation rates for the type of neighborhood, month, and number of days since last collection involved. The neighborhood types are defined as functions of the following link variables:

- Average floor area per residential unit
- Average number of persons per residential unit
- Average income per residential unit

The neighborhood types for which cumulative histograms have been developed for the model are defined in Appendix I.

Collection Subroutine II

The Collection Subroutine II determines the length of time it takes a collection vehicle of a commercial collection system to collect solid waste from a fixed-container location and the amount of solid waste collected. The logic of the Collection Subroutine II is illustrated by the flow chart in Figure V-4 in Appendix V.

When called by the Main Program, the Collection Subroutine II first determines the number of fixed containers to be dumped at the location. For each fixed container, it determines a dump time and an amount of solid waste dumped. It accumulates the sum of the dump times and the sum of the amounts of solid waste dumped and returns them to the Main Program as the collection time and the amount of solid waste collected for the fixed-container location.

The Collection Subroutine II draws the dump time for each fixed-container at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of dump times for the size of fixed containers and type of collection vehicle involved. It draws the amount of solid waste dumped for each fixed container at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of amounts of solid waste in fixed containers of the size involved.

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Collection Subroutine III

The Collection Subroutine III determines the length of time it takes a container transfer vehicle to dump a container train. The logic of the Collection Subroutine III is illustrated by the flow chart in Figure V-5 in Appendix V.

When called by the Main Program, the Collection Subroutine III draws a dump time at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of dump times for the size of container train and type of container transfer vehicle involved.

Weigh Subroutine

The Weigh Subroutine determines the length of time it takes a collection vehicle to weigh on the scales at its disposal site. The logic of the Weigh Subroutine is illustrated by the flow chart in Figure V-6 in Appendix V.

When called by the Main Program, the Weigh Subroutine draws a weighing time at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of weighing times for the type of collection vehicle and the particular disposal site involved.

Dump Subroutine

The Dump Subroutine determines the length of time it takes a collection vehicle to dump at its disposal site. The logic of the Dump Subroutine is illustrated by the flow chart in Figure V-7 in Appendix V.

When called by the Main Program, the Dump Subroutine draws a dump time at random from a probability distribution expressed in the form of a cumulative histogram that described the occurrence of dump times for the type of collection vehicle and the particular disposal site involved.

Prescheduled Activities Subroutine I

The Prescheduled Activities Subroutine I determines the time of occurrence of the first prescheduled activity of each collection vehicle that has at least one prescheduled activity and files these events in the Event Table. The logic of the Prescheduled Activities Subroutine I is illustrated by the flow chart in Figure V-8 in Appendix V.

When called by the Main Program, the Prescheduled Activities Subroutine I first determines whether or not there are any prescheduled activities. If there are none, it merely returns control to the Main Program.

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If there are prescheduled activities, the Prescheduled Activities Subroutine I calls the File Subroutine to enter into the Event Table for the first prescheduled activity of each collection vehicle that has at least one prescheduled activity a "start of prescheduled activity" event with a time of occurrence which has been read from the input tape by the input/output logic of the Main Program. The Prescheduled Activities Subroutine I determines the type of the event to be filed in accordance with the following rules:

- If the collection vehicle involved is a train of a container-train system, file an Event Type 6.
- If the collection vehicle involved is a container transfer vehicle of a container-train system, file an Event Type 25.
- If the collection vehicle involved is a collection vehicle of a residential collection system other than a container-train system, file an Event Type 42.
- If the collection vehicle involved is a collection vehicle of a commercial collection system, file an Event Type 57.

Prescheduled Activities Subroutine II

The Prescheduled Activities Subroutine II determines the duration of a prescheduled activity and the distance traveled by the collection vehicle involved during the prescheduled activity. The logic of the Prescheduled Activities Subroutine II is illustrated by the flow chart in Figure V-9 in Appendix V.

When called by the Main Program, the Prescheduled Activities Subroutine II first determines which collection vehicle is involved and which of its prescheduled activities is involved. Then, it finds the prescheduled activity's duration and the distance traveled which have been stored by the input/output logic of the Main Program, which has read these data from the input tape.

Prescheduled Activities Subroutine III

The Prescheduled Activities Subroutine III determines the time of occurrence of a collection vehicle's next prescheduled activity. The logic of the Prescheduled Activities Subroutine III is illustrated by the flow chart in Figure V-10 in Appendix V.

When called by the Main Program, the Prescheduled Activities Subroutine III first determines which collection vehicle is involved and whether or not it has another prescheduled activity (a next prescheduled activity). If it does not have another one, the Prescheduled Activities Subroutine III returns control to the Main Program. But, if it does have another one, the Prescheduled Activities Subroutine III finds the time of occurrence of its next prescheduled activity which has been stored by the input/output logic of the Main Program, which has read it from the input tape.

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Breakdown Subroutine I

The Breakdown Subroutine I determines the number of breakdowns to occur for each collection vehicle during the collection day, and for each collection vehicle that has at least one breakdown, it determines the time of occurrence of its first breakdown and files it in the Event Table. The logic of the Breakdown Subroutine I is illustrated by the flow chart in Figure V-11 in Appendix V.

When called by the Main Program, the Breakdown Subroutine I first determines the number of breakdowns for a collection vehicle. If the number of breakdowns is equal to zero, it then determines whether or not there is another collection vehicle for which the number of breakdowns must be determined. If there is another collection vehicle, it proceeds to determine the number of breakdowns the collection vehicle is to have. If there is not another collection vehicle, it returns control to the Main Program.

If the number of breakdowns for the collection vehicle is not equal to zero, the Breakdown Subroutine I draws a time of occurrence for its first breakdown at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of breakdowns for the type of collection vehicle involved. Then, it calls the File Subroutine to enter into the Event Table an event for the collection vehicle with a time of occurrence equal to that randomly selected for the breakdown. The Breakdown Subroutine I determines the type of the event to be filed in accordance with the following rules:

- If the collection vehicle involved is a train of a container-train system, file Event Type 8.
- If the collection vehicle involved is a container transfer vehicle of a container-train system, file an Event Type 27.
- If the collection vehicle involved is a collection vehicle of a residential collection system other than a container-train system, file an Event Type 44.
- If the collection vehicle involved is a collection vehicle of a commercial collection system, file an Event Type 59.

Next, the Breakdown Subroutine I determines whether or not there is another collection vehicle for which the number of breakdowns must be determined. If there is another collection vehicle, it proceeds to determine the number of breakdowns the collection vehicle is to have. If there is not another collection vehicle, it returns control to the Main Program.

The Breakdown Subroutine I determines the number of breakdowns that a collection vehicle is to have by drawing a number of breakdowns at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of the frequency of breakdowns for the type of collection vehicle involved.

Breakdown Subroutine II

The Breakdown Subroutine II determines the down time and the replacement time for a collection vehicle. The logic of the Breakdown Subroutine II is illustrated by the flow chart in Figure V-12 in Appendix V.

When called by the Main Program, the Breakdown Subroutine II draws a down time and a replacement time at random from probability distributions expressed in the form of cumulative histograms that describe the occurrence of down times and replacement times, respectively, for the type of collection vehicle involved.

Breakdown Subroutine III

The Breakdown Subroutine III determines the time of occurrence of a collection vehicle's next breakdown. The logic of the Breakdown Subroutine III is illustrated by the flow chart in Figure V-13 in Appendix V.

When called by the Main Program, the Breakdown Subroutine III first determines whether or not the collection vehicle is to have another breakdown. If it is to have another breakdown, the Breakdown Subroutine III draws a time of occurrence for its next breakdown at random from a probability distribution expressed in the form of a cumulative histogram that describes the occurrence of breakdowns for the type of collection vehicle involved. But if the collection vehicle is not to have another breakdown, the Breakdown Subroutine III returns control to the Main Program.

CHAPTER VII

UTILITY SUBPROGRAMS

UTILITY SUBPROGRAMS

FUNCTION

Utility Subprograms are called by the Main Program and Activity Subprograms to perform certain common operations. The subroutines which comprise the set of Utility Subprograms and their functions are the following:

- File Subroutine--Called to place events in the Event Table in chronological order.
- Remove Subroutine--Called to remove events from the Event Table and leave the remaining events in the Event Table in chronological order.
- Histogram Subroutine--Called to generate a value for a random variable which is defined by a probability distribution expressed in the form of a cumulative histogram.
- Random Number Subroutine--Called to generate a random number from a uniform probability distribution over the range (0., 1.).

LOGIC

The logic for the Utility Subprograms is illustrated by the flow charts in Appendix VI. A discussion of the logic of each of these subprograms follows.

File Subroutine

The File Subroutine is called to file events in the Event Table. It enters descriptions of events into the Event Table in such a way that the events are arranged in chronological order. The event description which is stored in the Event Table consists of the following information:

- Time of occurrence of the event
- Type of the event
- Identification number of the collection vehicle involved in the event

The logic of the File Subroutine is illustrated by the flow chart in Figure VI-1 in Appendix VI.

When called, the File Subroutine compares the time of occurrence of the event to be filed with that of the first (earliest) event in the Event Table. If the time of occurrence of the event to be filed is not less than that of the first event, the File Subroutine compares its time of occurrence with that of the second (next earliest) event in the Event Table, and so on until it finds the earliest event in the Event Table that has a time of occurrence that is greater than that of the

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event to be filed. When it finds this event, the File Subroutine moves it and all later events down one position in the Event Table and puts the event to be filed in the vacated position.

Remove Subroutine

The Remove Subroutine is called to remove events from the Event Table. It removes event descriptions in such a way that the events remaining in the Event Table are left in chronological order. The logic of the Remove Subroutine is illustrated by the flow chart in Figure VI-2 in Appendix VI.

When called, the Remove Subroutine first determines the position of the event to be removed from the Event Table. Then, it removes the event from its position in the Event Table and moves all subsequent events up one position in the Event Table.

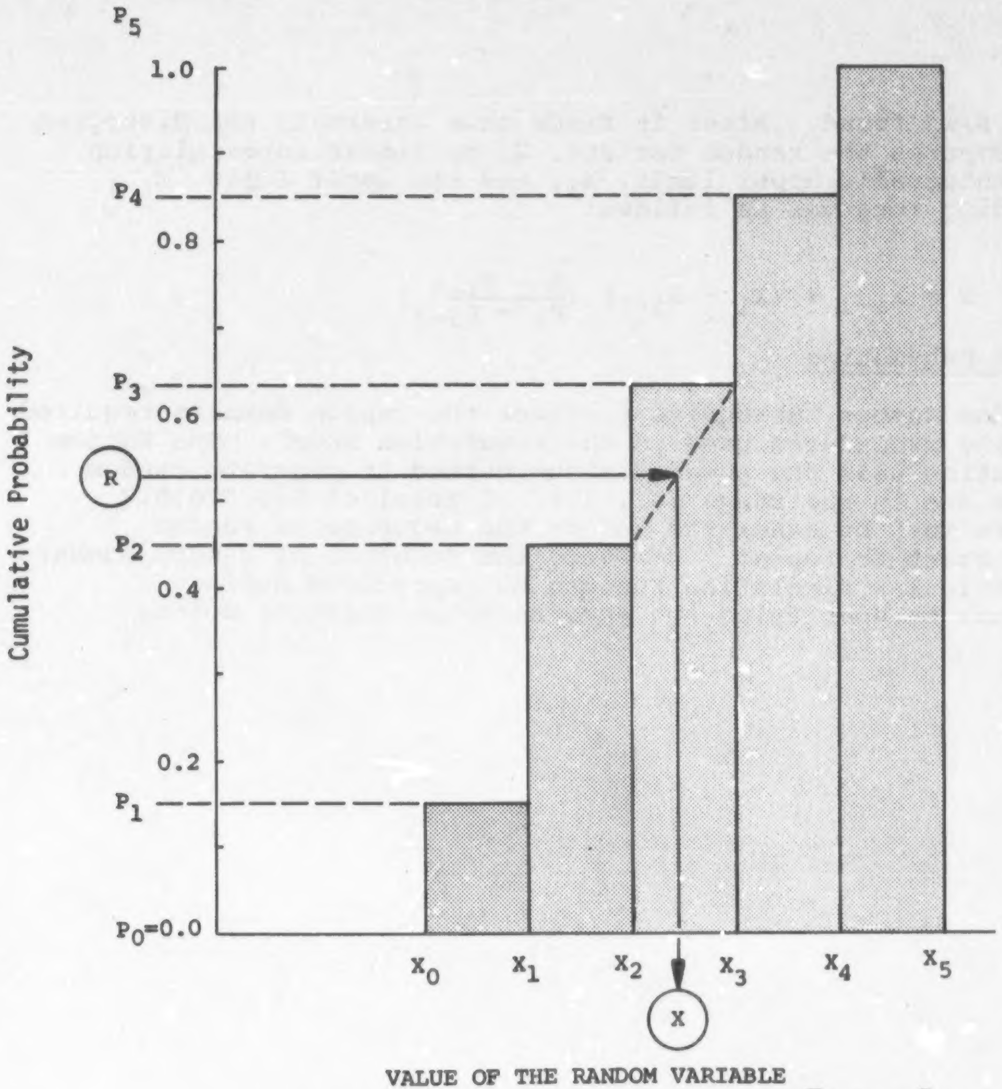
Histogram Subroutine

The Histogram Subroutine determines a value for a random variable which is defined by a probability distribution expressed in the form of a cumulative histogram. To generate the random variate, the Histogram Subroutine finds by linear interpolation the unique value that corresponds to a random number drawn from the distribution of the cumulative probabilities, which is a uniform distribution over the range (0., 1.). This method is illustrated in Figure 20. The logic of the Histogram Subroutine is illustrated by the flow chart in Figure VI-3 in Appendix VI.

When called, the Histogram Subroutine first identifies the random variables cumulative histogram which is defined in terms of the following:

- Number of equal-sized intervals, n, into which the range of the random variable is divided
- Lower limit, X_o, of the random variable's range
- Upper limit, X_n, of the random variable's range
- Cumulative probability, P_o, for the lower limit, X_o, of the random variable's range ($P_o = 0.0$)
- Cumulative probability, P_i, associated with each upper limit, X_i, of each interval of the random variable's range ($i = 1,2,3,\ldots,n$)

Next, the Histogram Subroutine calls the Random Number Subroutine to provide a random number, R, between 0.0 and 1.0. It then identifies the interval of the range, which contains the value X of the random variable associated with a cumulative probability equal to R, by comparing R with each P_i until the interval which has the lowest P_i



X = Random Variate = $X_i-1 + \left[X_i - X_{i-1}\right]\left[\frac{R-P_{i-1}}{P_i-P_{i-1}}\right]$

R = Random Number Between 0. and 1.

n = Number of Intervals

X_i = Upper Limit of ith Interval, i = 1,2,3,---n

X_0 = Lower Limit of Range

X_n = Upper Limit of Range

P_i = Cumulative Probability Corresponding
to X_i, i = 0,1,2,---n

ILLUSTRATION OF METHOD USED IN HIGTOGRAM
Figure 20

greater than R is found. After it finds this interval, the Histogram Subroutine computes the random variate, X, by linear interpolation between the interval's upper limit, X_i, and the upper limit, X_{i-1}, of the preceding interval as follows:

$$X = X_{i-1} + (X_i - X_{i-1}) \left(\frac{R - P_{i-1}}{P_i - P_{i-1}}\right)$$

Random Number Subroutine

The Random Number Subroutine provides the random numbers required in the sampling procedures used in the simulation model. The Random Number Subroutine uses the power residue method to generate random numbers which are in the range (0., 1.). A total of 533,670,912 random numbers must be generated before the sequence of random numbers will start to repeat. However, the sequence of random numbers used in a particular simulation run can be reproduced during subsequent runs by specifying the same sequence starting point.

CHAPTER VIII

OUTPUT PROGRAM MODULE

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OUTPUT PROGRAM MODULE

FUNCTION

The function of the Output Program Module is to input the results of a simulation run that are output on tape by the Simulation Program Module and print several reports that summarize the performance of the collection system simulated. The following reports can be printed by the Output Program Module:

- System description
- Event listing
- Disposal site reports
- Performance reports

However, only those reports requested by the user are output.

Report Contents

The contents of the reports that can be printed by the Output Program Module are summarized in this section.

System Description. The system description identifies the system and conditions simulated and serves as a reference to enhance analyses of the other reports. This report contains the following information:

- Alphanumeric information input as part of Data Set 1 to identify the simulation run
- Collection date (month and number of days since the last collection)
- Number of simulation iterations
- Number of street network areas
- For each headquarters:
  - Identification number
  - X-Y coordinates
  - Street-network-area number
- For each disposal site:
  - Identification number
  - X-Y coordinates
  - Street-network-area number
  - Number of scales
  - Number of dump channels
- Type of residential collection system and type of containers

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- For each residential collection vehicle:
  - Identification number
  - Capacity
  - Crew size
  - Convoy number (if any)
  - Headquarters number
  - Disposal site number
  - Collection route
- Type of commercial collection system
- For each commercial collection vehicle:
  - Identification number
  - Capacity
  - Crew size
  - Headquarters number
  - Disposal site number
  - Collection route
- Any optional performance characteristic input and the parameters of its cumulative histogram
- Any optional solid waste generation rate input and the parameters of its cumulative histogram
- For each prescheduled activity:
  - Identification number of collection vehicle involved
  - Time of occurrence
  - Duration
  - Distance traveled by collection vehicle involved

An example of this report is shown in Figure VII-1 in Appendix VII.

Event Listing. An event listing is a chronology of all the event which occur during the collection day simulated. The information printed for each event includes the following:

- Time of occurrence
- Identification number(s) of collection vehicle(s) involved
- Brief narrative description of the event and the performance of the associated activity by the collection vehicle(s) involved

An example of a portion of an event listing is shown in Figure VII-2 in Appendix VII.

Disposal Site Reports. The disposal site reports summarize the performance of the collection vehicles at the disposal sites. A disposal site report contains the following information:

- Disposal site description which includes:
  - Identification number
  - X-Y coordinates
  - Street-network-area number
  - Number of scales
  - Number of dumping channels
- For each collection vehicle that uses the disposal site:
  - Identification number
  - Total weighing time
  - Total dump time
  - Total waiting times at the disposal site
  - Total amount of solid waste dumped
- For all of the collection vehicles that use the disposal site:
  - Total weighing time
  - Total dump time
  - Total waiting times at the disposal site
  - Total amount of solid waste dumped
  - Total number of arrivals at the disposal site
- Maximum and average lengths of the queue of collection vehicles waiting to weigh at the disposal site
- Maximum and average lengths of the queue of collection vehicles waiting to dump at the disposal site

An example of a disposal site report is shown in Figure VII-3 in Appendix VII.

Performance Reports. The performance reports summarize the performance of the collection system simulated. The number and format of performance reports available for output depends on the type of collection system simulated. The following is a list of the ten specific performance reports available for each type of collection system:

- Residential collection systems:
  - Container-train system:
    - Train reports (Figure VII-4)
    - Container transfer vehicle reports (Figure VII-5)
    - Convoy reports (Figure VII-6)
    - System report (Figure VII-7)
  - Other residential collection systems:
    - Collection vehicle reports (Figure VII-8)
    - System report (Figure VII-9)

- Commercial collection systems:
  - Container-transfer-vehicle system:
    - Container transfer vehicle reports (Figure VII-10)
    - System report (Figure VII-11)
  - Packer-truck system:
    - Truck reports (Figure VII-12)
    - System report (Figure VII-13)

As indicated above, examples of these reports are shown in Figures VII-4 through VII-13 in Appendix VII.

Report Selection

The user has the options of either having all of the reports available printed or selecting only certain of them to be printed. Any one or combination of the following reports can be selected:

- Data description
- Event listing
- Disposal site reports
- Performance reports

Of the performance reports, all of them can be selected, or either the collection vehicle reports or the system reports can be selected. And, in the case of a container-train system, the convoy reports are also optional.

Report selections are input to the Output Program Module on a data card. The format of this card is shown in Table VII-1 in Appendix VII.

COMPONENTS

The Output Program Module reads a record from the tape output by the Simulation Program Module, and based on a record code contained in the record, it selects and executes the print instructions necessary to assemble the appropriate report. To generate the report lines, it utilizes a series of internal tables. A description of the various tables contained in the Output Program Module follows.

Data Area Table

The Data Area Table is where the variable data used by the print instructions to assemble a report line are stored. Each record read by the Output Program Module is placed in the Data Area Table for processing. Each data item stored in the Data Area Table is described in the Data Descriptor Table. However, if a record contains multiple occurrences of the same type of data, the data are described

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only once in the Data Descriptor Table and all occurrences of the data are moved to a common portion of the Data Area Table. Data required by the Output Program Module but not available on any input record, such as page number, are placed in a separate portion of the Data Area Table.

Data Descriptor Table

The Data Descriptor Table contains the location and size of each data item in the Data Area Table. Also included is an indication of how each data item is to be printed (e.g., suppress leading zeros, add the abbreviation "LBS" at the end, insert a dollar sign at the front).

Character String Table

The Character String Table contains all constants and literals that are used in the reports. Each unique sequence of characters used in the reports is assigned a sequence number and stored in this table. Also, a description of each of these sequences is stored in the String Descriptor Table. A particular sequence is referenced by the print instructions by its sequence, or string, number.

String Descriptor Table

The String Descriptor Table contains a description for each sequence in the Character String Table. The description indicates the location of the sequence in the Character String Table and the number of characters in the sequence.

Print Instructions Table

The Print Instructions Table contains coded instructions which indicate how each report is to be printed. Each instruction is four characters in length. The first three characters are numeric, and the fourth character is one of the following format codes:

- Blank - print a line after single spacing
- Zero - print a line after double spacing
- Minus sign - print a line after triple spacing
- One - print a line after skipping to the top of the next page
- X - skip a space in the line

If the fourth character is an "X", the first three characters of the instruction indicate the number of spaces to be skipped in the printed line. But, if the fourth character is not an "X", the first three characters indicate that either a sequence of characters from the Character String Table or a data item from the Data Area Table is to be placed in the printed line. If the value of the first three characters is less than 500, a sequence of characters from the Character String Table is to be placed in the printed line.

And, the first three characters specify the entry in the String Descriptor Table that indicates the location and size of the sequence of characters to be inserted in the printed line. If the value of the first three characters is greater than 500, a data item from the Data Area Table is to be placed in the printed line. And, the first three characters specify the entry in the Data Descriptor Table that indicates the location and size of the data item to be inserted in the printed line and any special printing instruction such as suppress leading zeros, add the abbreviation "LBS" at the end, or insert a dollar sign in front of the data.

Starting Instruction Table

The Starting Instruction Table contains the first instruction in the Print Instructions Table for each input record type.

Performance Report Heading Table

The Performance Report Heading Table contains the first instruction in the Print Instructions Table for the heading of each of the ten performance report formats.

Report Line Table

The Report Line Table contains indexes to instructions in the Print Instructions Table for each line of the body of each of the ten performance report formats.

Report Start Table

The Report Start Table contains an entry for each of the ten performance report formats which indicates where in the Report Line Table the first line of the body of the report can be found.

Event Listing Table

The Event Listing Table contains an entry for each event listing format which indicates the instruction in the Print Instructions Table to be used as the first print instruction for the event listing. Each entry in this table also specifies the number of lines required for printing the event listing so that it can be printed on only one page.

LOGIC

The logic of the Output Program Module is composed of the following basic steps, beginning with the first record on the tape output by the Simulation Program Module:

(1) Read a record.

(2) Move data on the record into the Data Area Table.

(3) Determine the type of the record.

(4) On the basis of the record type, locate in the Starting Instruction Table the first instruction for processing the record data.

(5) Execute the first instruction, which will cause either one of the following to occur:

- Record data to be stored in a separate portion of the Data Area Table for use in printing subsequent reports

- Report to be printed

If the report to be printed is one of the ten performance reports, the following tables are used to determine the appropriate sequence of print instructions:

- Performance Report Heading Table
- Report Start Table
- Report Line Table

If the report to be printed is an event listing, the Event Listing Table is used to determine the first print instruction.

(6) Repeat Steps 1 through 5 until all of the records have been read and processed.

A flow chart of this logic is shown in Figure 21.

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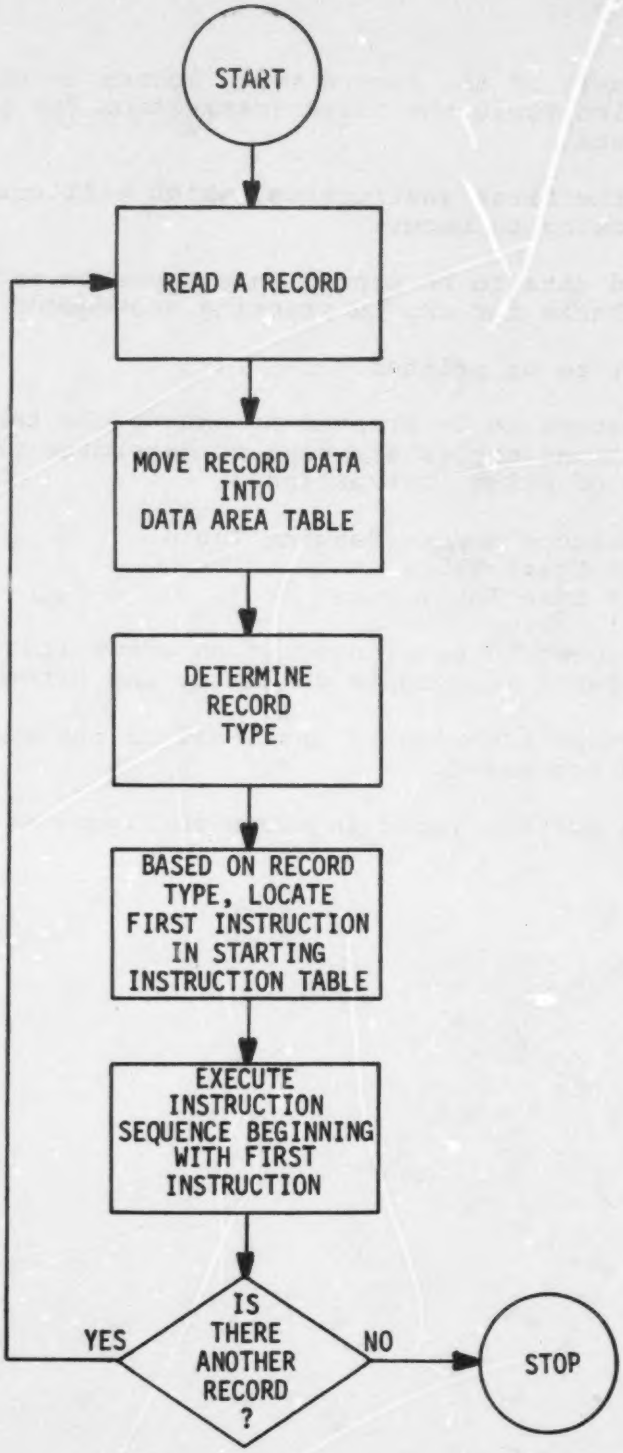
START
READ A RECORD
MOVE RECORD DATA INTO DATA AREA TABLE
DETERMINE RECORD TYPE
BASED ON RECORD TYPE, LOCATE FIRST INSTRUCTION IN STARTING INSTRUCTION TABLE
EXECUTE INSTRUCTION SEQUENCE BEGINNING WITH FIRST INSTRUCTION
IS THERE ANOTHER RECORD ?
YES
NO
STOP

BASIC LOGIC OF OUTPUT PROGRAM MODULE

Figure 21

CHAPTER IX

SIMULATION MODEL DEMONSTRATION

SIMULATION MODEL DEMONSTRATION

TESTING

In general, the acceptability of the simulation model output depends mainly on: (1) the validity of the performance characteristics and solid waste generation rates used and (2) the realism of the logic of the simulation program module with respect to the system and conditions being simulated. The values used for the performance characteristics and solid waste generation rates are represented in the form of cumulative histograms. Cumulative histograms of performance characteristics and solid waste generation rates are provided in the model for some of the systems and conditions for which it is designed to simulate. (The cumulative histograms included in the model are presented in Appendix I.) However, the flexibility of the model is such that other cumulative histograms that are more representative of the system and conditions being simulated can be input as optional performance characteristics and optional solid waste generation rates and used instead of those provided in the model. Thus, the applicability of the simulation model is not restricted by the validity of the performance characteristics and solid waste generation rates it provides. Therefore, testing of the simulation model other than program debugging was limited to checking the logic of the simulation program module.

The rationale of the logic of the simulation program module is the construction of a calendar of system events for the collection day by integrating the operational sequences of the collection vehicles. Since the operational sequences of the collection vehicles of the types of systems for which the model is designed to simulate are well-defined, the test of the logic was primarily concerned with verifying event calendars constructed by the model.

Several configurations of each type of system operating under various conditions were simulated so that all branches of the logic were executed. The event listing for each simulation was examined to assure that it did not contain any sequence of events that was contrary to the operational sequences of the collection vehicles involved. As errors were noted, the necessary corrections were made to the model. Testing was continued until it was determined that the model generated valid event calendars for all system configurations and operating conditions.

WICHITA FALLS CONTAINER-TRAIN SYSTEM SIMULATION

As a demonstration of the ability of the model to represent the solid waste collection system of an entire city, it was used to simulate a collection day for the Wichita Falls container-train system.

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System

The Wichita Falls container-train system is composed of 20 trains and 5 container transfer vehicles which are organized into 5 convoys. Each convoy consists of 4 trains and a container transfer vehicle. The trains collect solid waste from the residential units. The container transfer vehicle dumps the trains when they are loaded and hauls the solid waste to the disposal site as the trains continue with their routes. The container transfer vehicle is also assigned a commercial collection route comprised of commercial collection units located within the proximity of the train routes.

In Wichita Falls, solid waste is collected twice a week on a residential collection route: either on Mondays and Thursdays or on Tuesdays and Fridays. There is a total of 40 residential collection routes. Each train is assigned two routes: a Monday-Thursday route and a Tuesday-Friday route.

On a commercial collection route, the frequency of collection depends on the needs of the particular land use being served. Some commercial collection units are served once a week, others twice a week or even daily, and some more than once a day. Therefore, the commercial collection routes are not as well-defined as the residential collection routes, and they are assigned to the container transfer vehicles on a daily basis.

Each train has a capacity of 3600 pounds of solid waste and a 3-man crew. Each container transfer vehicle has a capacity of 10,000 pounds of solid waste and a one-man crew consisting of only a driver.

Collection Conditions

The residential collection route assignments used in the simulation were 20 of the adjusted route assignments which were determined for Wichita Falls during the demonstration of the automated route selection and evaluation procedures presented in Volume I, Section Two of this final project report. The 20 route assignments used are the trains' Monday-Thursday routes. These routes are designated as Route Nos. 21-40 in Figure 22.

The commercial collection routes used were determined by arbitrarily assigning to each container transfer vehicle 20 commercial collection units located within its convoy area. The convoys were organized as follows:

CTV No.	Route/Train Nos.
1	21-24
2	25-28
3	29-32
4	33-36
5	37-40

The sequence of the collection units in each commercial route was established heuristically with the intention of minimizing the travel time between them.

The simulation was conducted for a Monday (4 days since the last collection) in the month of June. In Wichita Falls, this combination represents a heavy collection workload condition.

The headquarters and disposal site locations used are shown in Figure 22. The disposal site is a landfill site. It has no scales, but it does have several dumping channels so that queues of collection vehicles waiting to dump do not occur.

The breakdown characteristics of the container-train system in Wichita Falls were determined as shown in Appendix I. However, those of other systems were not observed. Therefore, in order to facilitate subsequent comparison of the container-train system with other residential collection systems for Wichita Falls in this demonstration, the effects of breakdowns weren't included. Also, there were no prescheduled activities included.

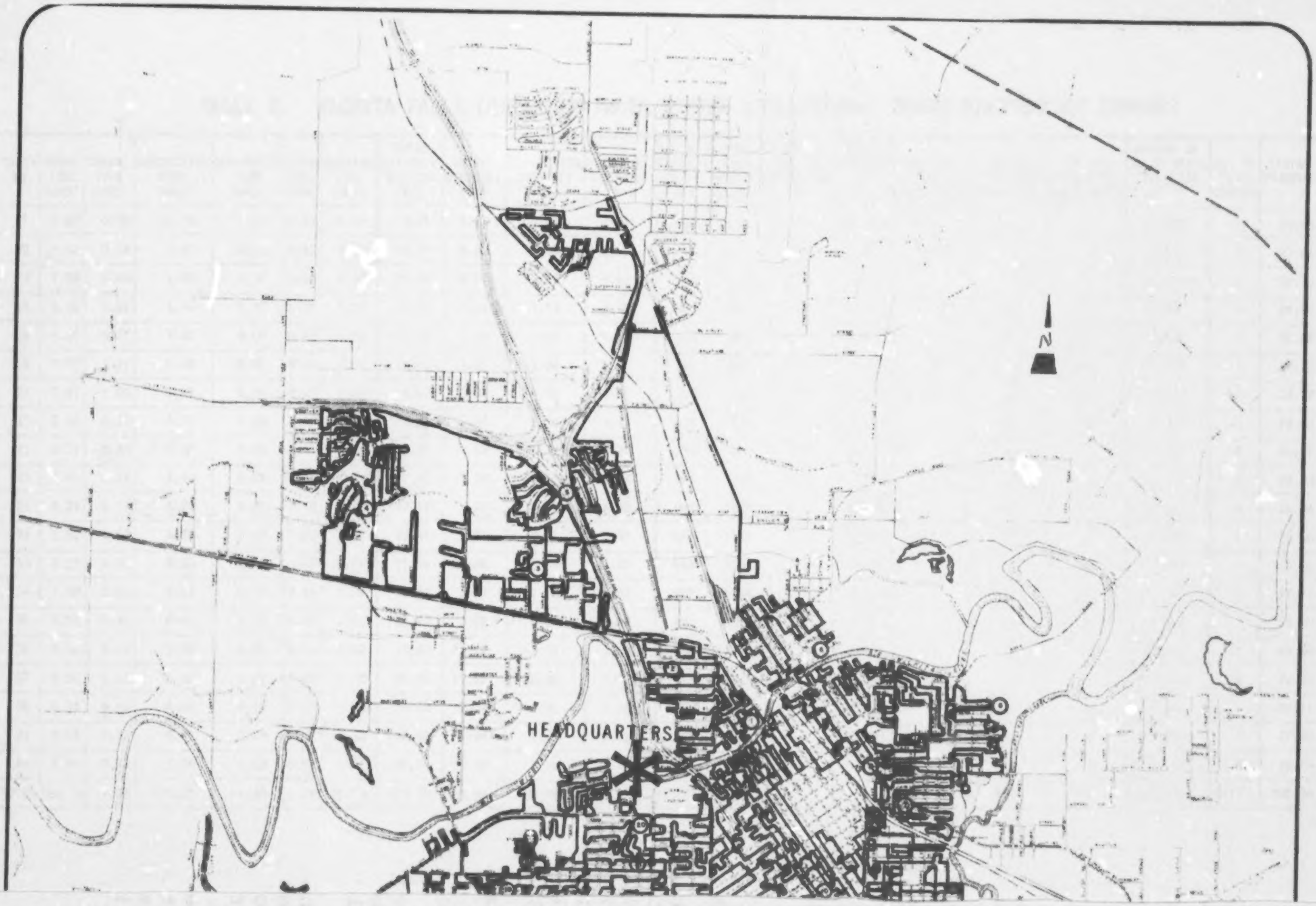
Results

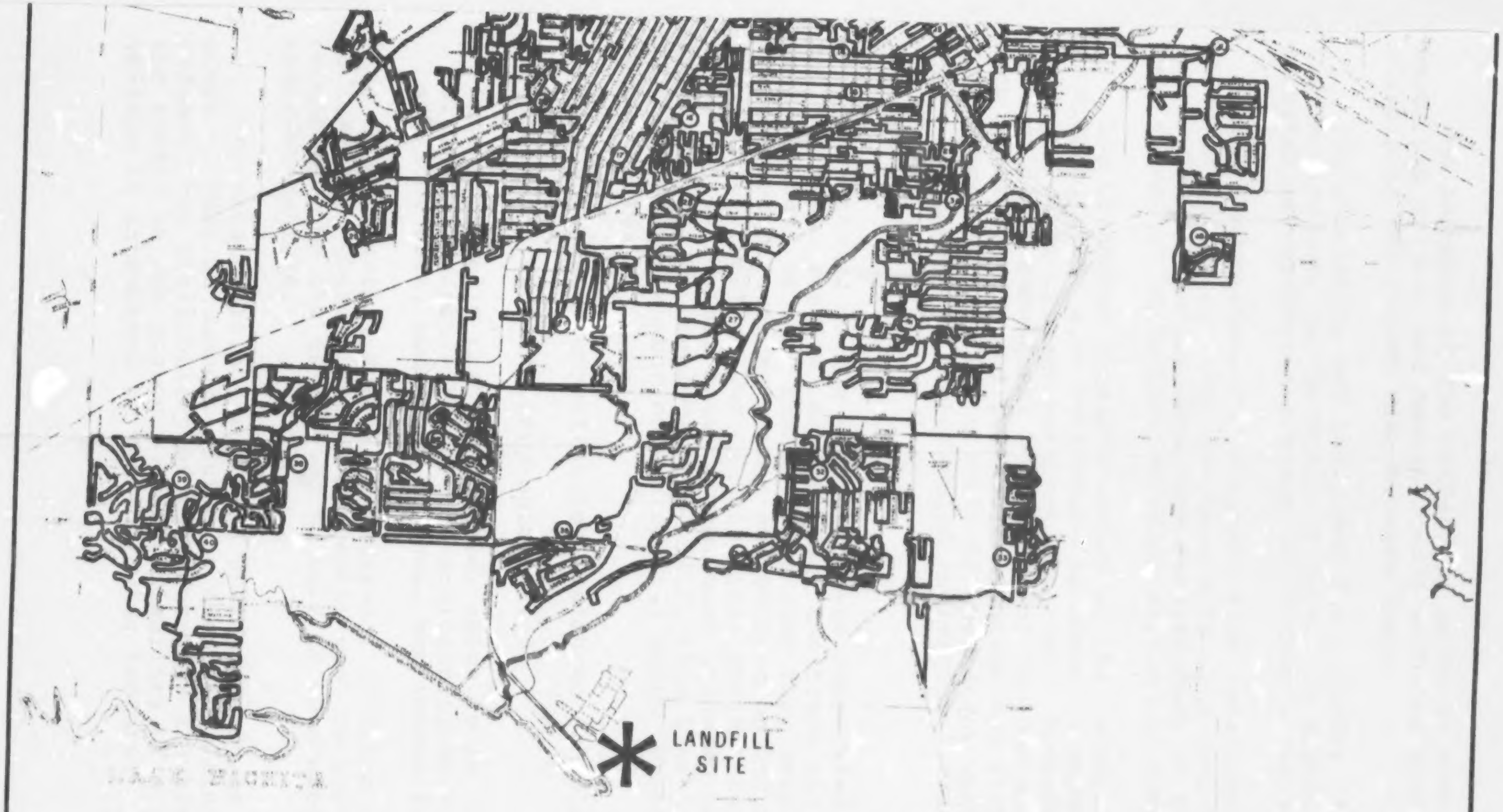
The results of the simulation are summarized in Tables 4 and 5. These results indicate that the train routes are generally well-balanced as they should be because they were designed using the automated route selection and evaluation techniques described in Volume I, Section Two of this final project report. It should be noted that these routes were balanced on the basis of time required to complete them. And, this time is not only a function of the number of residential units served, but is also dependent on:

- Collection and non-collection distances traveled
- Number and type of carry-outs served
- Amount of solid waste collected, which is in turn a function of the characteristics of the residential units served, such as floor area, number of persons, and income level

Thus, the principal source of imbalance in terms of total time indicated by these simulation results was the variation in the amount of time the trains had to wait to be dumped by a container transfer vehicle.

The total waiting time of a train depends on the number of times it must be dumped. But, the average waiting times per dump reflects the availability of the container transfer vehicle to the trains in its convoy. The availability of a container transfer vehicle is determined by the following factors:


N
HEADQUARTERS


LANDFILL SITE
LAKE WICHITA

NOTE:
O *denotes beginning point of route*

ROUTE ASSIGNMENTS FOR WICHITA FALLS CONTAINER - TRAIN SYSTEM

Figure 22

TABLE 4. WICHITA FALLS CONTAINER-TRAIN SYSTEM SIMULATION: TRAIN PERFORMANCE SUMMARY

TRAIN NO.	TOTAL TIME (HRS)	TRAVEL TIME (HRS)	COLLECTION TIME (HRS)	NON-COLL. TIME (HRS)	DUMP TIME (HRS)	WAITING TIME (HRS)	TOTAL DISTANCE TRAVELED (MI)	TRAVEL DISTANCE (MI)	COLLECTION DISTANCE (MI)	NON-COLL. DISTANCE (MI)	NO. OF RESID. UNITS (RU)	AVG. FLOOR AREA/RU (SQ.FT.)	AVG. NO. OF PERSONS/ RU	AVG. INCOME/ RU ($)	NO. OF TYPE-ONE CARRY-OUTS	NO. OF TYPE-TWO CARRY-OUTS	NO. OF TYPE-THREE CARRY-OUTS	AMOUNT OF SOLID WASTE COLLECTED (LBS)	NO. OF TIMES DUMPED	TOTAL MANHOURS	CONVOY NO.
21	7.88	0.28	6.12	0.18	0.45	0.85	13.91	5.57	5.67	2.67	828	1040	2.2	10,178	0	1	0	21,463	6	23.65	1
22	9.02	0.44	5.81	0.19	0.60	1.98	20.70	8.80	8.98	2.92	758	1485	2.7	11,019	0	0	0	28,299	8	27.06	1
23	7.58	0.44	5.65	0.34	0.52	0.63	24.23	8.74	9.89	5.60	724	1494	2.6	10,435	0	1	0	25,410	7	22.73	1
24	8.15	0.31	6.49	0.12	0.38	0.85	13.85	6.23	5.64	1.98	517	1691	2.4	16,746	17	63	51	19,557	5	24.45	1
25	8.09	0.27	7.09	0.09	0.22	0.42	10.78	5.39	3.86	1.53	198	2628	2.2	23,210	0	25	154	10,230	3	24.28	2
26	7.77	0.21	6.84	0.08	0.22	0.42	9.41	4.17	3.98	1.26	198	2427	2.2	19,660	21	17	149	9,509	3	23.32	2
27	7.91	0.20	6.81	0.05	0.22	0.63	8.67	3.95	4.17	0.55	309	1613	2.1	13,871	13	56	107	10,630	3	23.72	2
28	8.16	0.17	6.57	0.09	0.37	0.96	9.62	3.34	5.16	1.12	694	1090	2.1	8,382	52	21	34	17,635	5	24.47	2
29	8.31	0.20	6.28	0.16	0.37	1.30	11.71	4.03	5.39	2.29	768	903	2.1	8,367	9	42	1	17,127	5	24,93	3
30	7.68	0.27	5.95	0.22	0.37	0.87	17.31	5.35	8.63	3.33	786	794	2.5	7,414	0	0	0	19,019	5	23.03	3
31	8.21	0.33	6.28	0.20	0.45	0.95	17.41	6.58	7.47	3.37	663	1237	2.8	12,462	2	49	17	22,753	6	24.64	3
32	8.52	0.40	5.84	0.34	0.52	1.42	22.81	7.99	9.21	5.61	654	1499	2.7	12,404	0	25	12	24,440	7	25.56	3
33	8.29	0.45	5.65	0.22	0.45	1.52	21.84	9.08	8.39	3.77	644	1408	2.8	11,033	0	50	0	23,647	6	24.86	4
34	7.59	0.38	6.22	0.17	0.45	0.37	17.84	7.67	7.14	3.03	537	1788	2.9	14,119	0	89	26	23,562	6	22.77	4
35	8.03	0.45	5.85	0.18	0.53	1.02	21.43	9.08	9.27	3.08	591	1892	2.4	17,551	0	37	22	24,566	7	24.09	4
36	8.18	0.56	5.94	0.09	0.52	1.07	18.62	11.17	6.12	1.33	816	1008	3.1	9,581	0	0	0	27,005	7	24.54	4
37	8.35	0.55	6.22	0.23	0.45	0.90	21.60	11.07	6.94	3.59	814	1027	2.8	10,000	0	4	5	24,811	6	25.05	5
38	8.70	0.60	6.23	0.12	0.37	1.38	19.79	12.04	6.05	1.70	474	1430	3.0	11,316	0	27	66	18,556	5	26.11	5
39	9.15	0.72	5.44	0.19	0.60	2.20	24.47	14.29	7.06	3.12	737	1338	3.4	12,670	0	0	0	30,566	8	27.46	5
40	9.55	0.76	5.94	0.22	0.68	1.95	26.78	15.30	7.76	3.72	801	1089	3.7	10,010	0	0	0	31,984	9	28.64	5
TOTAL	165.12	7.99	123.22	3.48	8.74	21.69	352.19	159.84	136.78	55.57	12,511	-	-	-	114	507	644	430,769	117	495.36	-

TABLE 5. WICHITA FALLS CONTAINER-TRAIN SYSTEM SIMULATION-CONTAINER TRANSFER VEHICLE SUMMARY

CTV NO.	TOTAL TIME (HRS)	TRAVEL TIME (HRS)	COLLECTION TIME (HRS)	DUMP TIME (HRS)	TIME WAITING TO DUMP TRAINS (HRS)	TIME WAITING AT DISPOSAL SITE (HRS)	TOTAL DISTANCE TRAVELED (MI)	NO. OF TRIPS TO DISPOSAL SITE	NO. OF TRAINS DUMPED	NO. OF FIXED CONTAINERS DUMPED	TOTAL AMOUNT OF SOLID WASTE COLLECTED (LBS)	AMOUNT OF SOLID WASTE COLLECTED FROM TRAINS (LBS)	AMOUNT OF SOLID WASTE COLLECTED FROM F.C.'S (LBS)	TOTAL MANHOURS	CONVOY NO.
1	10.01	3.18	2.56	1.26	3.01	0.00	119.54	9	26	20	100,329	94,729	5,600	10.01	1
2	9.36	2.36	1.72	0.70	4.58	0.00	90.04	5	14	22	54,254	48,004	6,250	9.36	2
3	9.53	2.80	2.33	1.12	3.28	0.00	104.45	8	23	20	89,189	83,339	5,850	9.53	3
4	9.18	2.75	2.59	1.26	2.58	0.00	102.54	9	26	21	104,930	98,780	6,150	9.18	4
5	10.34	3.67	2.77	1.40	2.50	0.00	137.20	10	28	22	112,317	105,917	6,400	10.34	5
TOTAL	48.42	14.76	11.97	5.74	15.95	0.00	553.77	41	117	105	461,019	430,769	30,250	48.42	-

- Number and location of commercial collection units assigned
- Compactness of convoy area
- Distance between convoy area and disposal site
- Number of train loads

The average train waiting times per dump for the convoys computed from the simulation results are:

Convoy No.	Avg. Train Waiting Time Per Dump
1	0.17 hrs
2	0.17 hrs
3	0.20 hrs
4	0.15 hrs
5	0.22 hrs

These averages indicate that the container transfer vehicles in Convoy Nos. 3 and 5 were not as available as those in the other convoys. Of course, their availability could be improved by redesigning their commercial collection routes.

Comparison with Other Residential Collection Systems

The simulation model was also used to determine the performance of some other types of residential collection systems for the same conditions used in the Wichita Falls container-train system simulation. The following systems were simulated:

- Container-train system, without carry-out service (Wichita Falls, Texas)
- Packer-truck system (College Station, Texas)
- Alley/street-container system (Odessa, Texas)
- Mechanical-bag-retriever system (Bellaire, Texas)

The performance characteristics used for each system were those observed for a similar system in the cities cited. As mentioned previously, the effects of breakdowns were not considered. In other words, the systems were assumed to be equally reliable.

A description of these systems and a summary of the simulation results are presented in Table 6. These results together with cost data for each system could be used to determine which of these systems is most efficient and economical for the collection conditions considered. However, it is apparent from a comparison of the simulation results that:

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TABLE 6. COMPARISON OF RESIDENTIAL COLLECTION SYSTEMS FOR WICHITA FALLS

SYSTEM	CAPACITY (LBS)	CREW SIZE	TYPE OF STORAGE CONTAINER	CARRY-OUT SERVICE PROVIDED	TOTAL TIME (HRS)	TRAVEL TIME (HRS)	COLLECTION TIME (HRS)	NON-COLL TIME (HRS)	DUMP TIME (HRS)	WAITING TIME (HRS)	TOTAL DISTANCE TRAVELED (MI)	TRAVEL DISTANCE (MI)	COLLECTION DISTANCE (MI)	NON-COLL. DISTANCE (MI)	NO. OF LOADS	NO. OF TRIPS TO DISPOSAL SITE	TOTAL MANHOURS
WICHITA FALLS CONTAINER-TRAIN	3,600	3	CAN	YES	165.12	7.99	123.22	3.48	8.74	21.69	352.19	159.84	136.78	55.57	117	-	495.36*
WICHITA FALLS CONATINER-TRAIN	3,600	3	CAN	NO	135.51	7.99	93.61	3.48	8.74	21.69	352.19	159.84	136.78	55.57	117	-	406.53*
COLLEGE STATION PACKER-TRUCK	11,000	3	BAG	NO	95.87	18.58	67.93	3.88	5.48	0.00	655.61	463.26	136.78	55.57	39	39	287.61
ODESSA ALLEY/ STREET-CONTAINER	18,700	1	ALLEY/STR. CONTAINER	NO	104.58	16.04	78.88	6.43	3.23	0.00	531.13	338.78	136.78	55.57	23	23	104.58
BELLAIRE MECHANICAL-BAG-RETRIEVER	11,000	1	BAG	NO	121.14	19.65	92.88	3.13	5.48	0.00	655.61	463.26	136.78	55.57	39	39	121.14

*Container transfer vehicle performance statistics are not included in these totals.

- If carry-out service was eliminated in Wichita Falls, the total workload would be reduced by over 30 hours, which for an 8-hour collection day is equivalent to nearly 4 route assignments. Therefore, 16 trains would be required instead of 20.

- The Odessa, alley/street-container system requires the fewest manhours.

In making these comparisons, it should be noted that the system totals for the container-train systems do not include the performance statistics for the container transfer vehicles.

USE OF THE SIMULATION MODEL

The simulation model can be used to simultaneously simulate the residential and commercial collection systems of a city. The system can be of the following types, or of other types which have components and an operation similar to these:

- Residential Systems:
  - Container-train systems
  - Packer-truck systems
  - Alley/street-container systems
  - Mechanical-bag-retriever systems

- Commercial Systems:
  - Container-transfer-vehicle systems
  - Packer-truck systems

The components and operation of these systems are described in Chapter II.

For each type of system, the model can account for system and condition changes with respect to the following:

- Headquarter locations

- Disposal site locations and number of scales and dumping channels at each disposal site

- Number of collection vehicles and the capacity, crew size, headquarters, disposal site, and collection route assignment of each

- Collection route design

- Performance characteristics of the collection vehicles such as collection rates, travel speeds, dump times, and reliability (breakdown frequency, occurrence, and downtimes)

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- Solid waste generation rates as a function of land use changes, month of the year, and number of days since the last collection

- Prescheduled activities of the collection vehicles

The maximum size of the system that can be simulated in terms of the numbers of collection vehicles, headquarters, disposal sites, and collection units depends on the computer system used to run the model. The model can be adjusted accordingly by an experienced FORTRAN IV programmer.

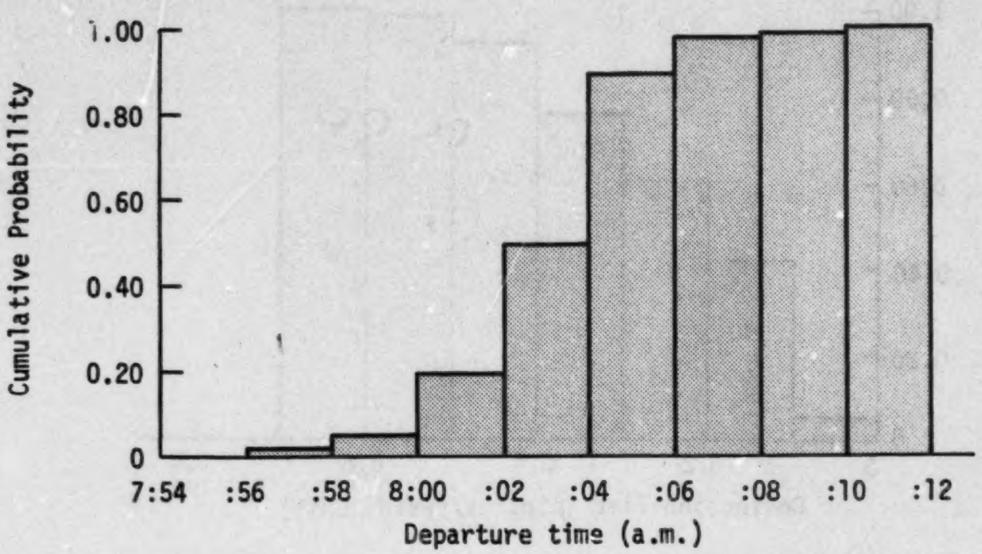
CONCLUSIONS

The simulation model described and demonstrated in this report can be used as a valuable tool for the planning and management of solid waste collection systems. Because the model requires a computer readable representation of the collection routes, its effectiveness is increased when it is used in conjunction with the automated solid waste management techniques described in Volume I, Sections One and Two of this final project report.

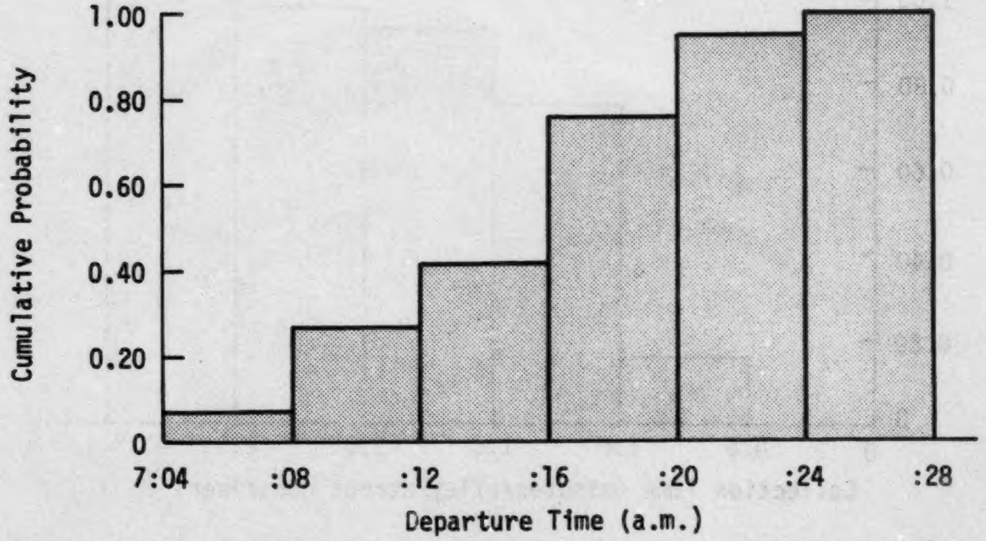
APPENDIX I

CUMULATIVE HISTOGRAMS OF PERFORMANCE CHARACTERISTICS AND SOLID WASTE GENERATION RATES

DEPARTURE TIMES*



TRAIN DEPARTURE TIMES



CONTAINER TRANSFER VEHICLE DEPARTURE TIMES

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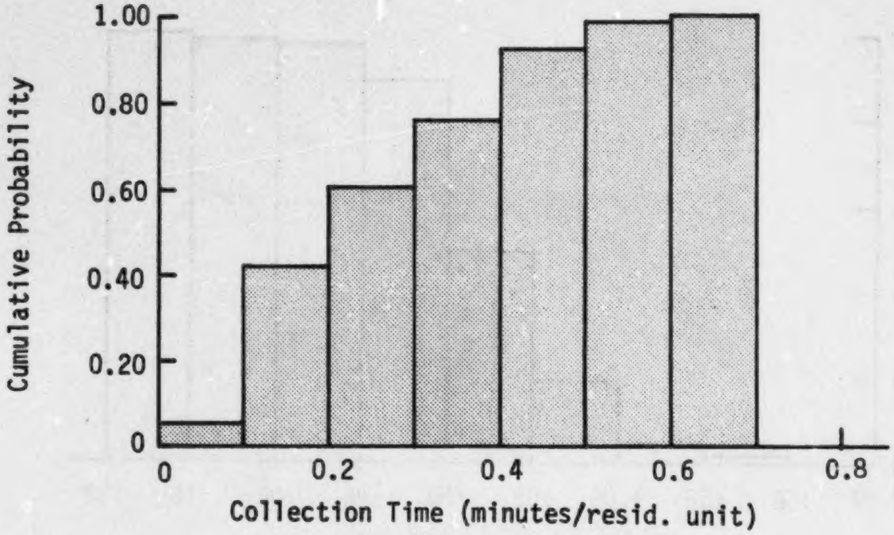
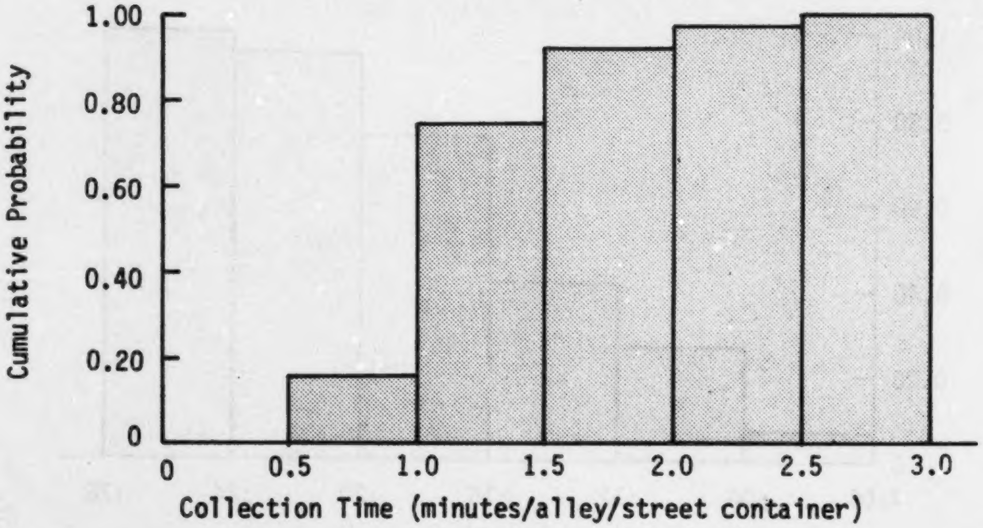
*Developed from data collected on container-train system in Wichita Falls, Texas

Figure I - 1



TRAIN COLLECTION TIMES PER RESIDENTIAL UNIT*
(THREE-MAN CREW, CANS, ALL LINK CODES, ALL LINK SURFACES,
FOUR DAYS SINCE LAST COLLECTION)



ALLEY/STREET-CONTAINER COLLECTION TIMES PER ALLEY/STREET CONTAINER**
(ONE-MAN CREW, ALL LINK CODES, ALL LINK SURFACES,
FOUR DAYS SINCE LAST COLLECTION)

Figure I - 2

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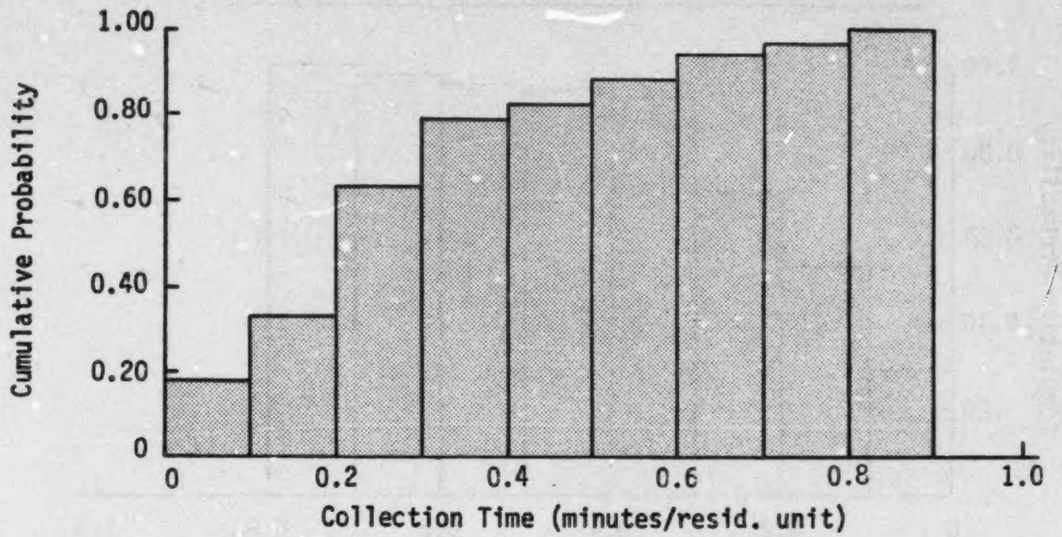
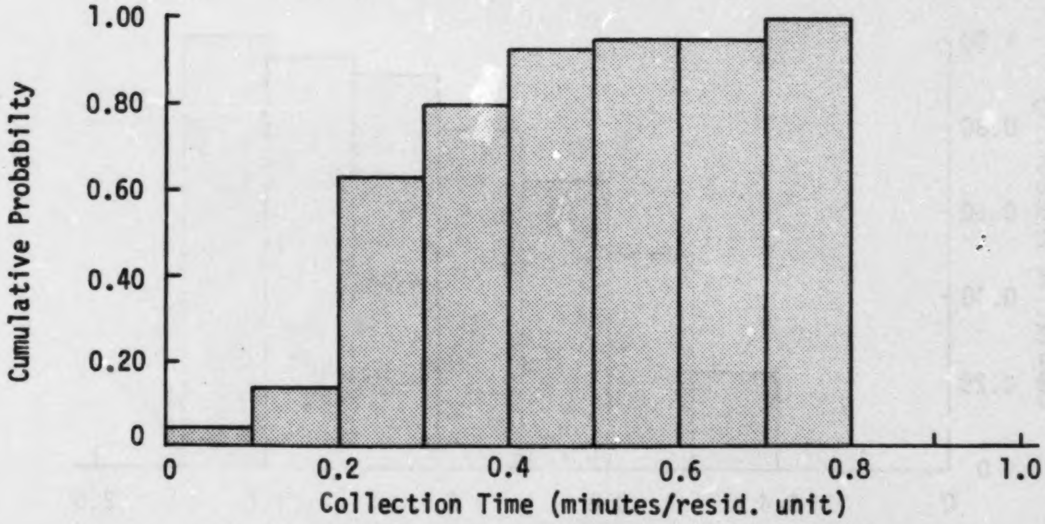
COLLECTION TIMES PER RESIDENTIAL UNIT (CONT'D)



MECHANICAL BAG RETRIEVER COLLECTION TIMES PER RESIDENTIAL UNIT***
(ONE-MAN CREW, BAGS, ALL LINK CODES, ALL LINK SURFACES,
FOUR DAYS SINCE LAST COLLECTION)



PACKER TRUCK COLLECTION TIMES PER RESIDENTIAL UNIT****

(THREE-MAN CREW, BAGS, ALL LINK CODES, ALL LINK SURFACES,
FOUR DAYS SINCE LAST COLLECTION)

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*Developed from data collected on container-train system in Wichita Falls, Texas

**Developed from data collected on alley/street-container system in Bellaire, Texas

***Developed from data collected on mechanical-bag-retriever system in Bellaire, Texas

****Developed from data collected on packer-truck system in College Station, Texas

Figure I - 3

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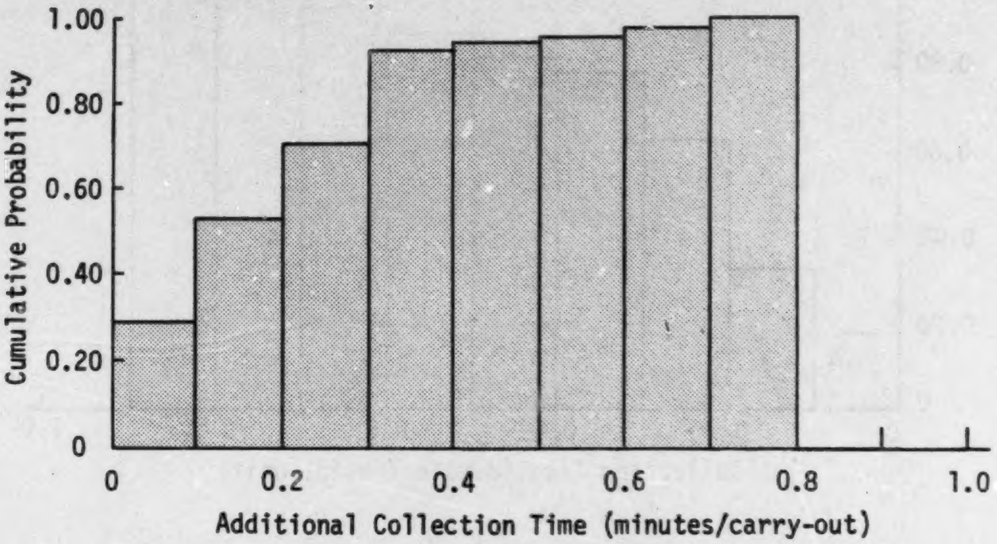
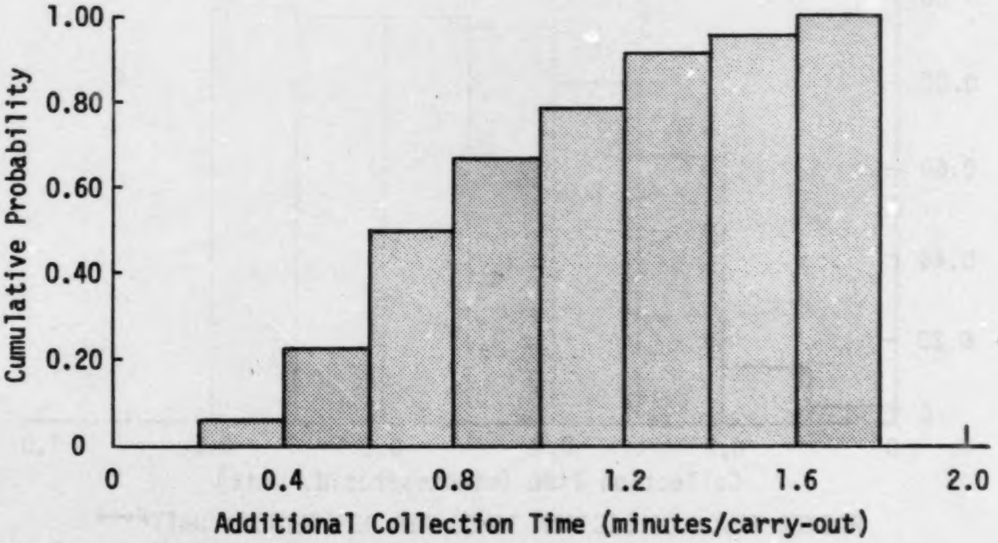
ADDITIONAL COLLECTION TIMES PER CARRY-OUT*



ADDITIONAL COLLECTION TIMES PER TYPE-ONE CARRY-OUT
(THREE-MAN CREW, CANS, ALL LINK CODES, FOUR DAYS SINCE LAST COLLECTION)



ADDITIONAL COLLECTION TIME PER TYPE-TWO CARRY-OUT
(THREE-MAN CREW, CANS, ALL LINK CODES, FOUR DAYS SINCE LAST COLLECTION)

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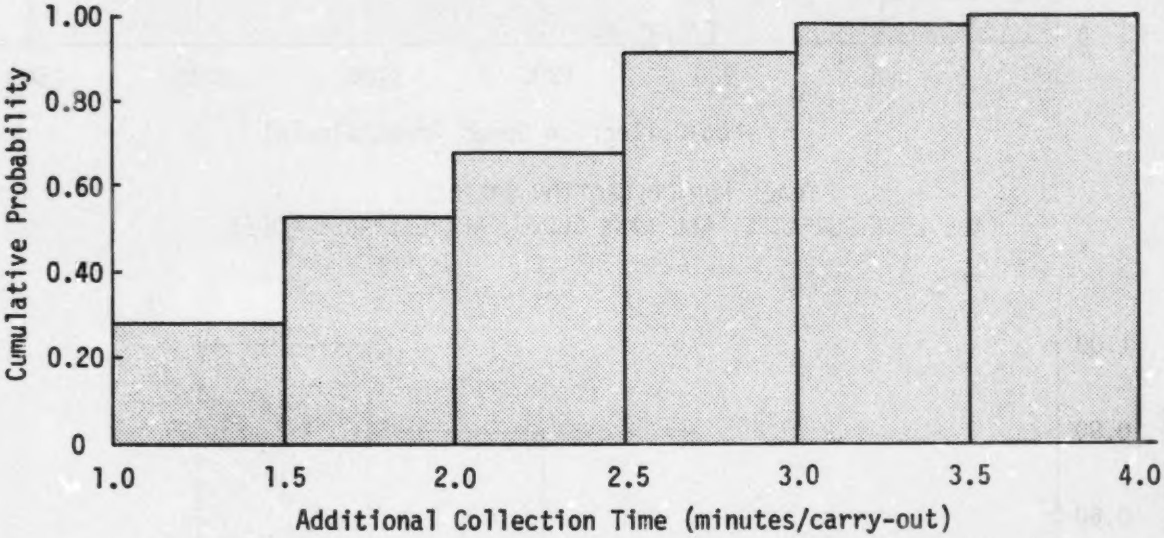
*Developed from data collected on container-train system in Wichita Falls, Texas

Figure I - 4

ADDITIONAL COLLECTION TIMES PER CARRY-OUT (CONT'D.)



ADDITIONAL COLLECTION TIME PER TYPE-THREE CARRY-OUT
(THREE-MAN CREW, CANS, ALL LINK CODES, FOUR DAYS SINCE LAST COLLECTION)

Figure I - 5

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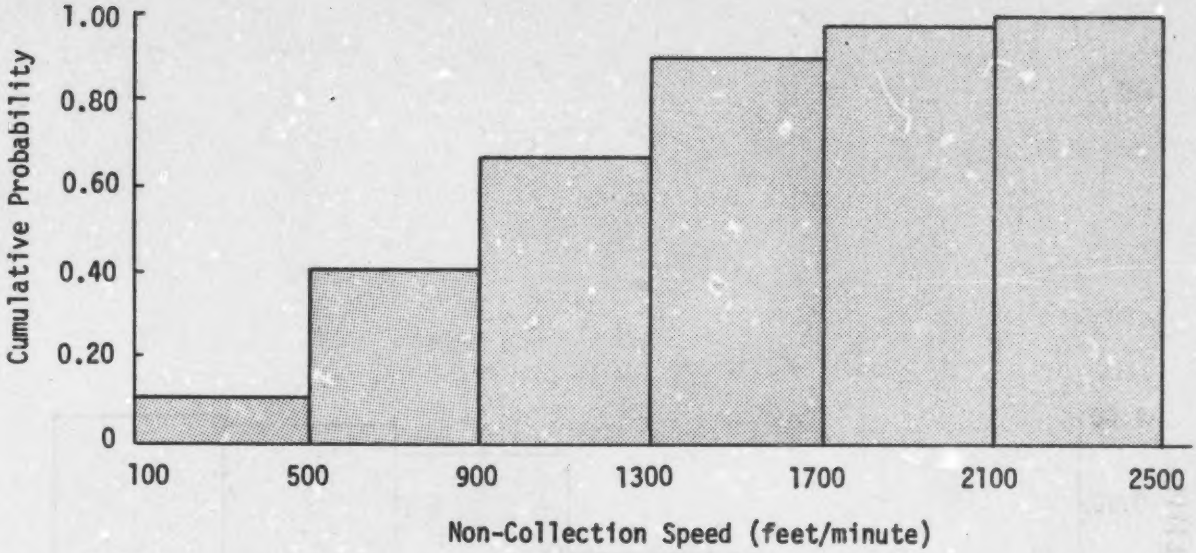
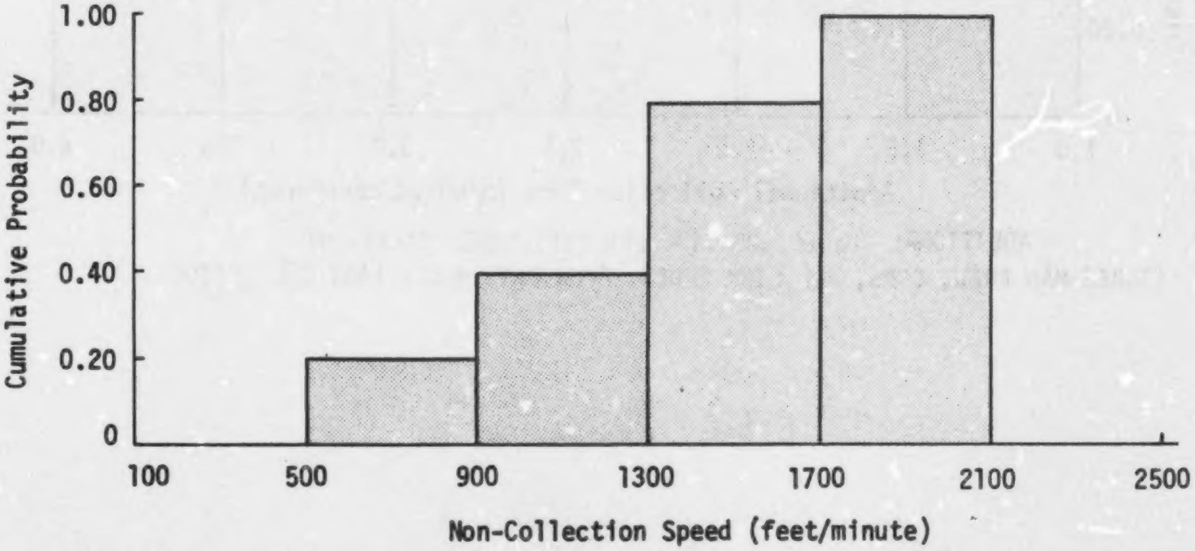
NON-COLLECTION SPEEDS



TRAIN NON-COLLECTION SPEEDS*
(ALL LINK SURFACES, ALL LINK CODES, ALL DISTANCE CODES)



ALLEY/STREET-CONTAINER COLLECTION VEHICLE NON-COLLECTION SPEEDS**
(ALL LINK SURFACES, NON-COLLECTION LINKS, ALL DISTANCE CODES)

Figure I - 6

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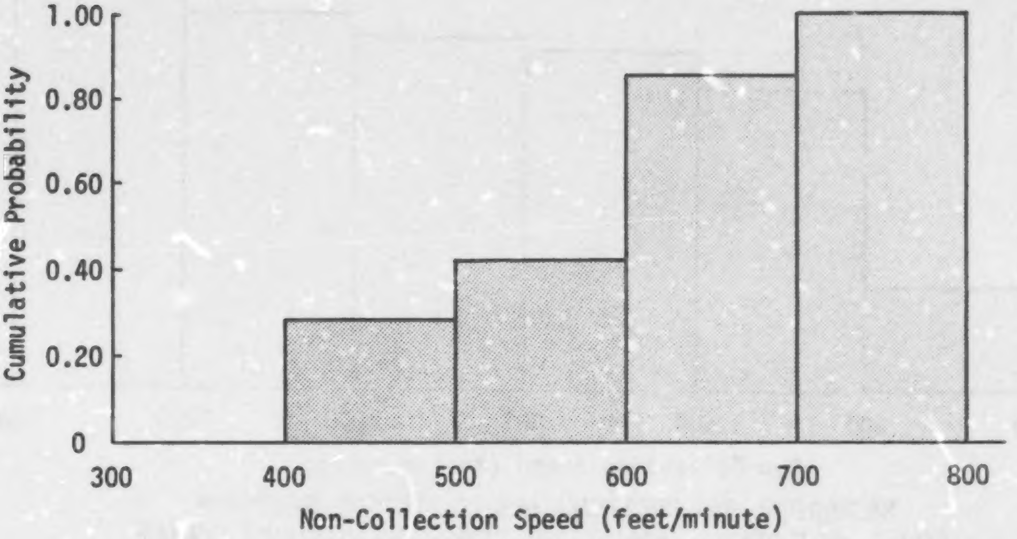
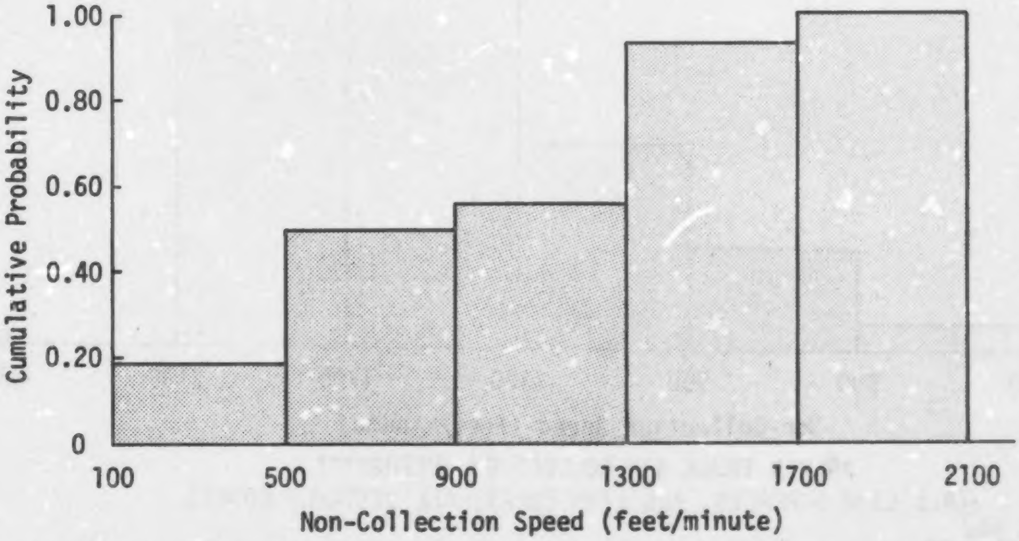
NON-COLLECTION SPEEDS (CONT'D.)



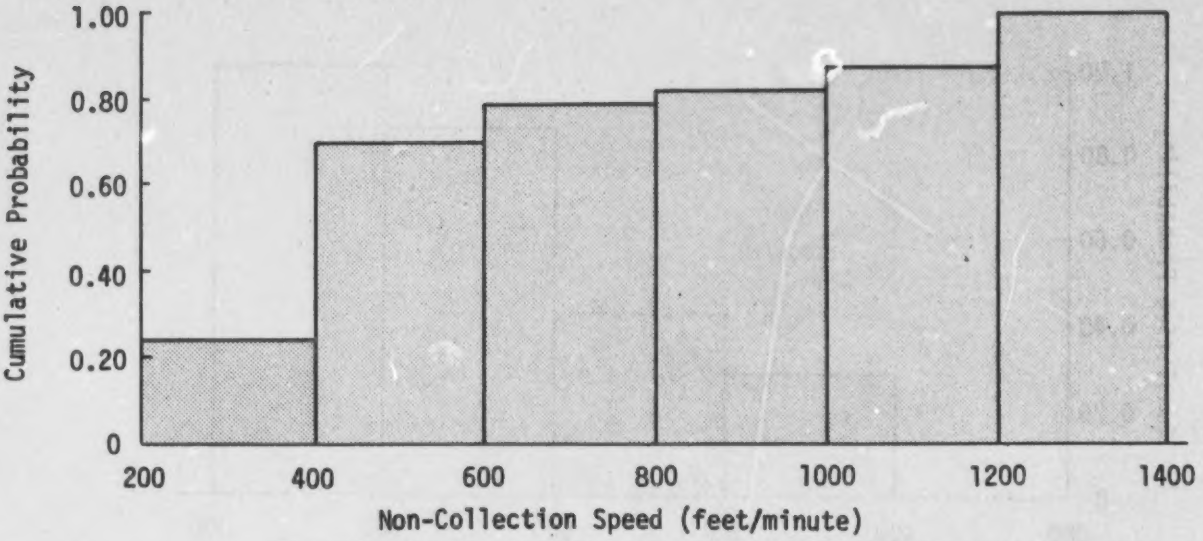
ALLEY/STREET-CONTAINER COLLECTION VEHICLE NON-COLLECTION SPEEDS**
(ALL LINK SURFACES, COLLECTION LINKS, ALL DISTANCES CODES)



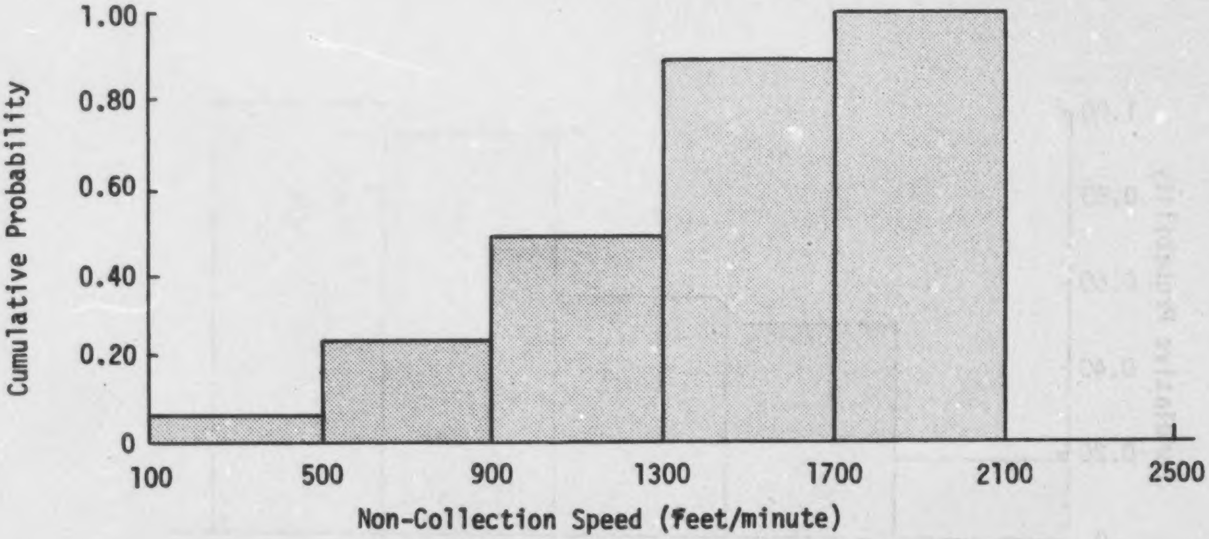
MECHANICAL BAG RETRIEVER NON-COLLECTION SPEEDS***
(ALL LINK SURFACES, NON-COLLECTION LINKS, ALL DISTANCE CODES)

Figure I - 7

NON-COLLECTION SPEEDS (CONT'D.)



MECHANICAL BAG RETRIEVER NON-COLLECTION SPEEDS***
(ALL LINK SURFACES, COLLECTION LINKS, ALL DISTANCE CODES)



PACKER TRUCK NON-COLLECTION SPEEDS****
(ALL LINK SURFACES, ALL LINK CODES, ALL DISTANCE CODES)

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*Developed from data collected on container-train system in Wichita Falls, Texas
**Developed from data collected on alley/street-container system in Abilene, Texas
***Developed from data collected on mechanical-bag-retriever system in Bellaire, Texas
****Developed from data collected on packer-truck system in College Station, Texas

Figure I - 8

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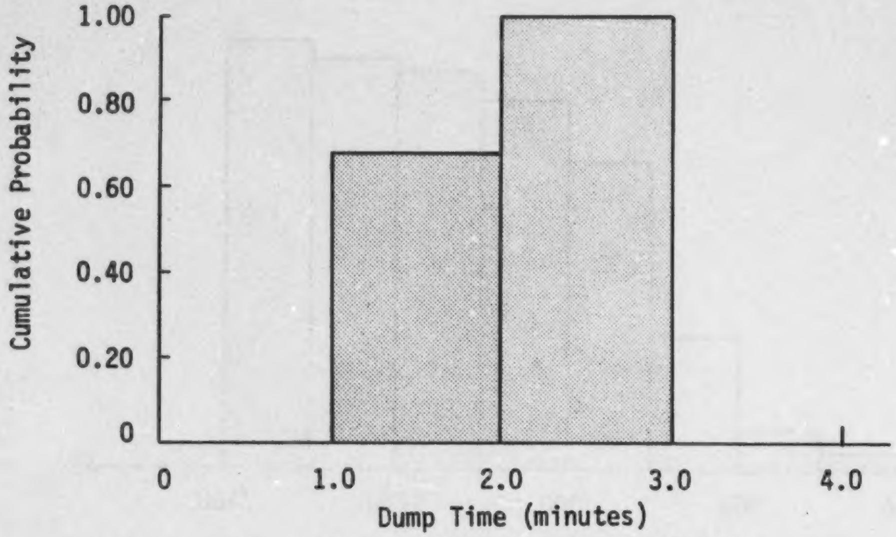
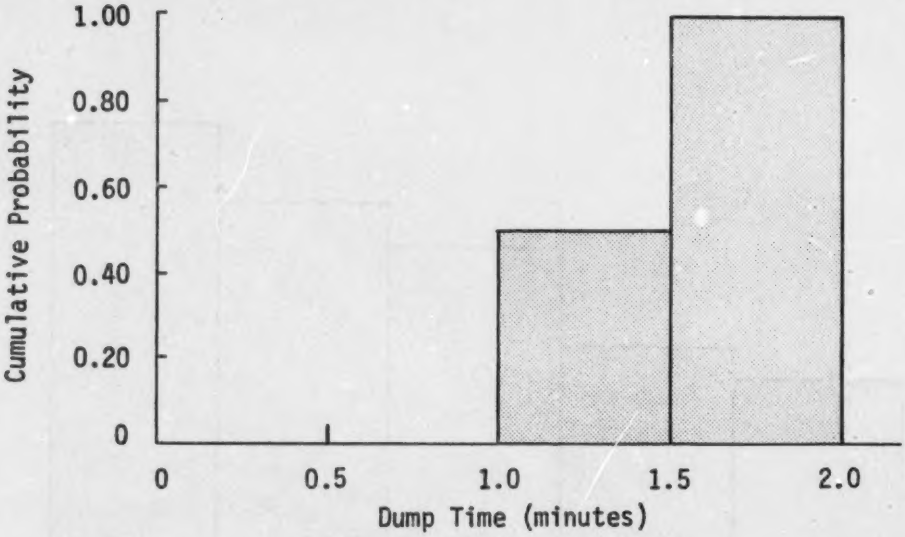
CONTAINER DUMP TIMES*



FIXED CONTAINER DUMP TIMES (3, 4, & 8 cu.yd.)



TRAIN CONTAINER DUMP TIMES

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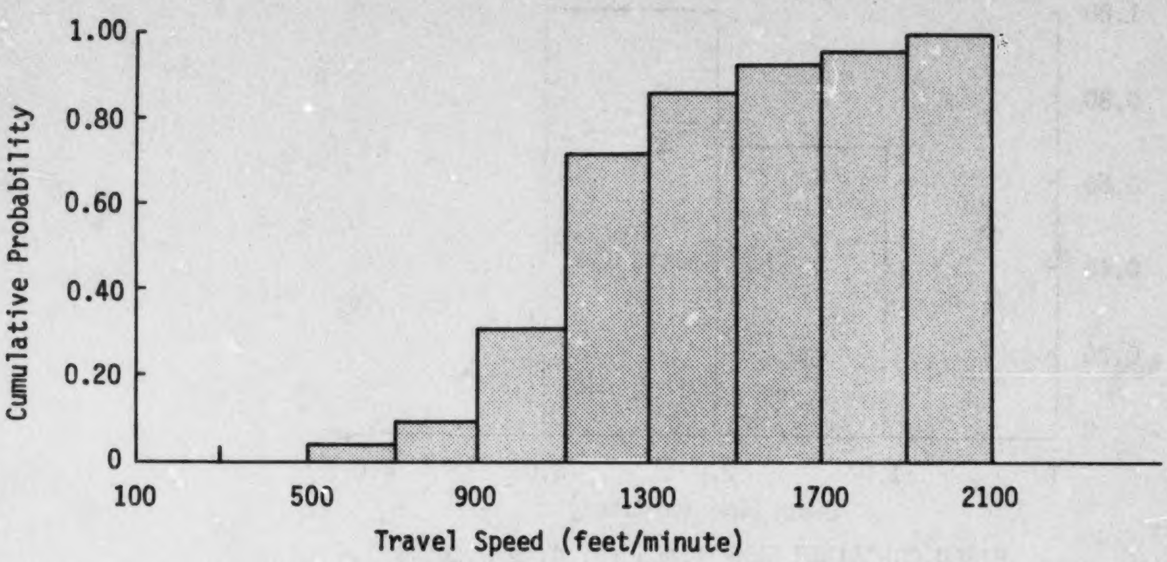
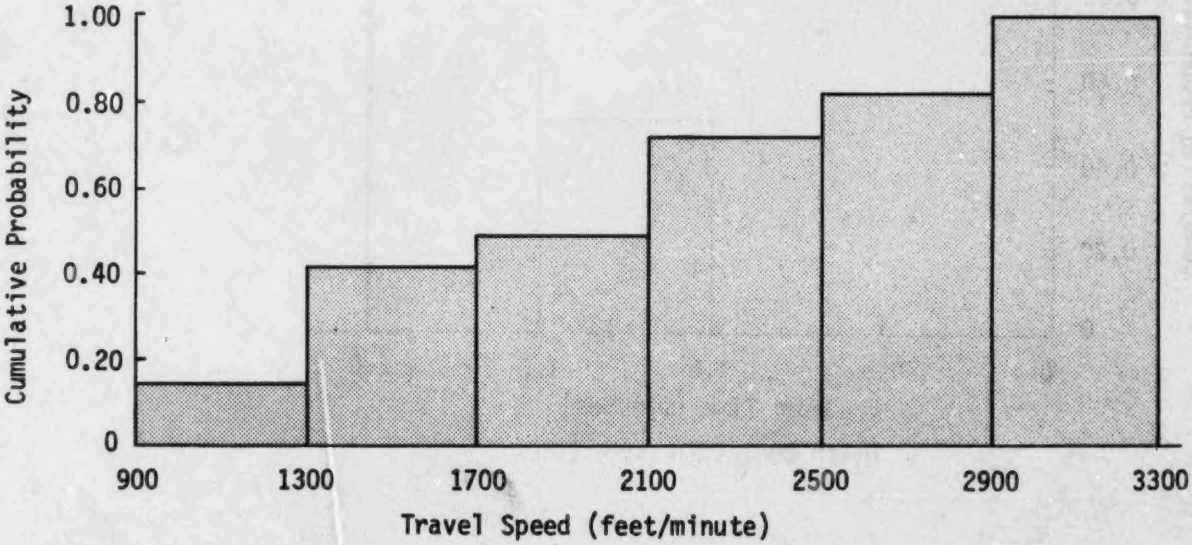
*Developed from data collected on container-train system in Wichita Falls, Texas

Figure I - 9

TRAVEL SPEEDS



TRAIN TRAVEL SPEEDS*
(ALL DISTANCE CODES)



CONTAINER TRANSFER VEHICLE TRAVEL SPEEDS*
(ALL DISTANCE CODES)

Figure I - 10

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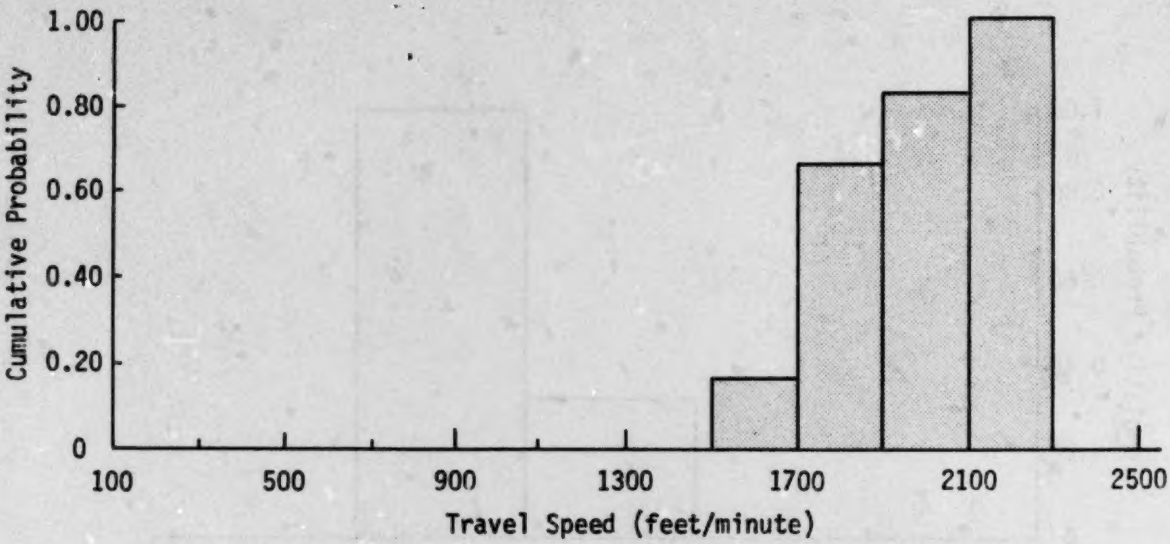
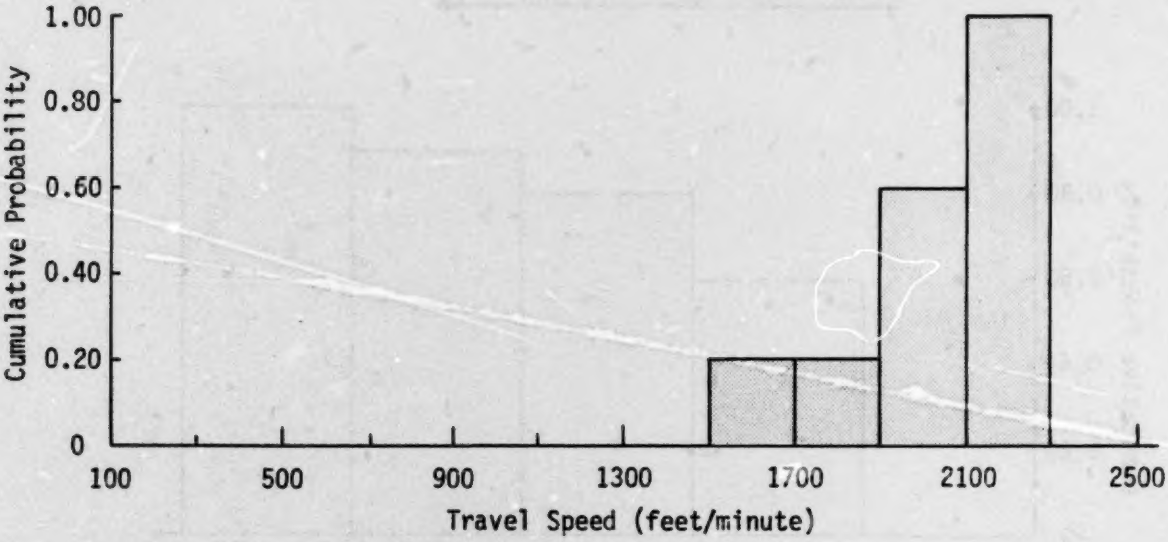
TRAVEL SPEEDS (CONT'D)



ALLEY/STREET-CONTAINER COLLECTION VEHICLE TRAVEL SPEEDS**
(ALL DISTANCE CODES)



MECHANICAL BAG RETRIEVER TRAVEL SPEEDS***
(ALL DISTANCE CODES)

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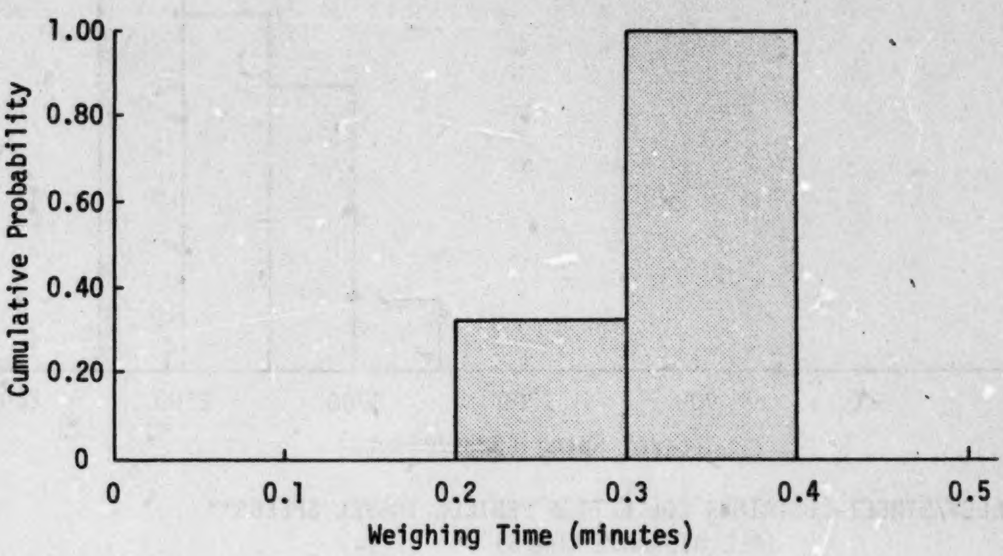
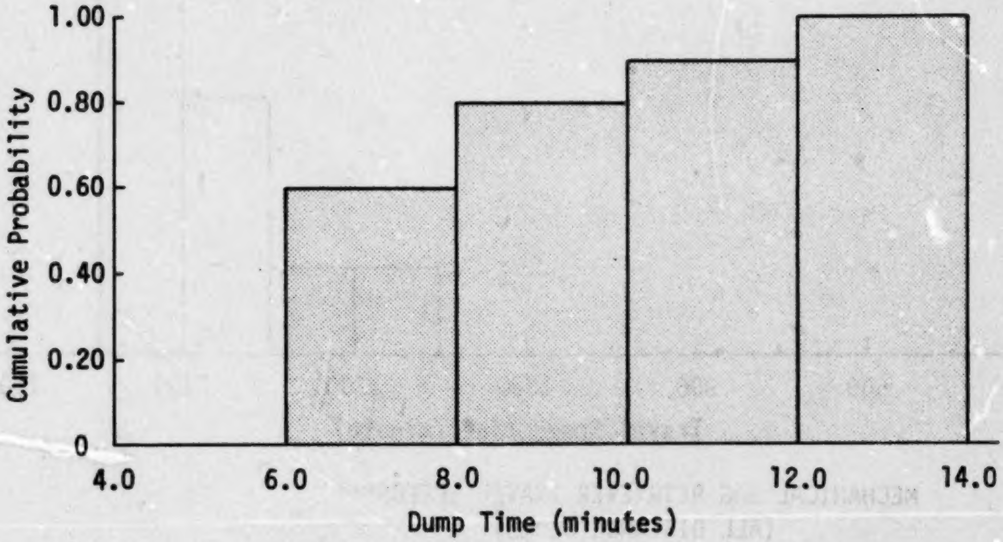
*Developed from data collected on container-train system in Wichita Falls, Texas
**Developed from data collected on alley/street-container system in Abilene, Texas
***Developed from data collected on mechanical-bag-retriever system in Bellaire, Texas

Figure I - 11

WEIGHING TIMES AT DISPOSAL SITE*



DUMP TIMES AT DISPOSAL SITE*



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*Developed from data collected on container-train system in Wichita Falls, Texas

Figure I - 12

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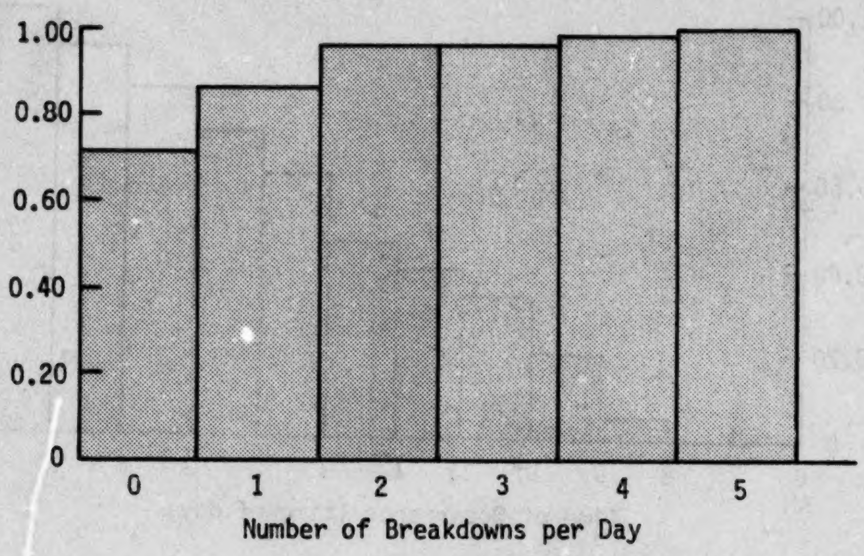
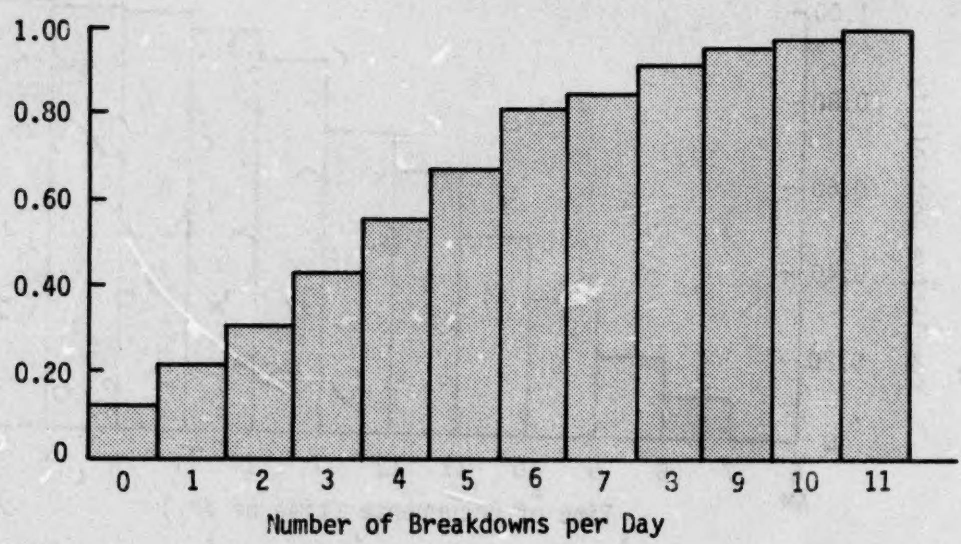
BREAKDOWN FREQUENCY*



TRAIN BREAKDOWN FREQUENCY



CONTAINER TRANSFER VEHICLE BREAKDOWN FREQUENCY

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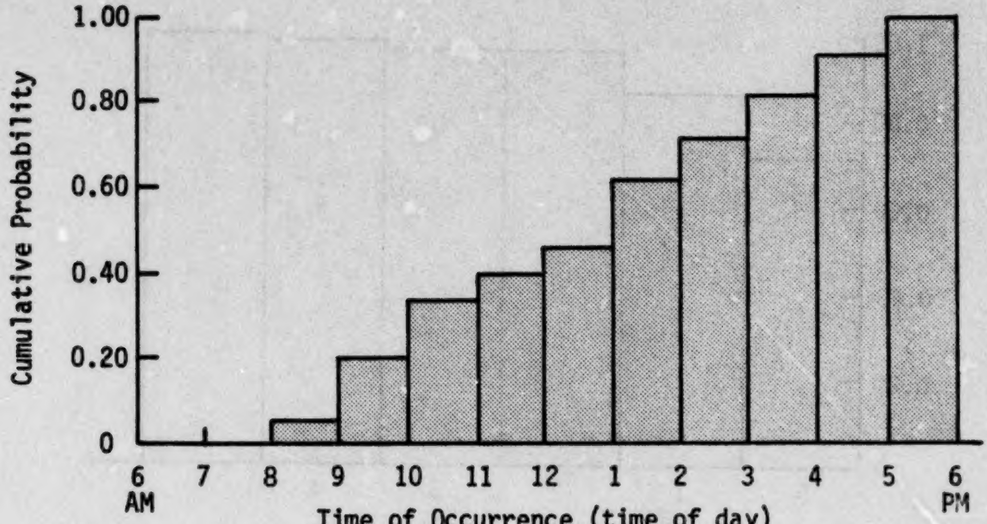
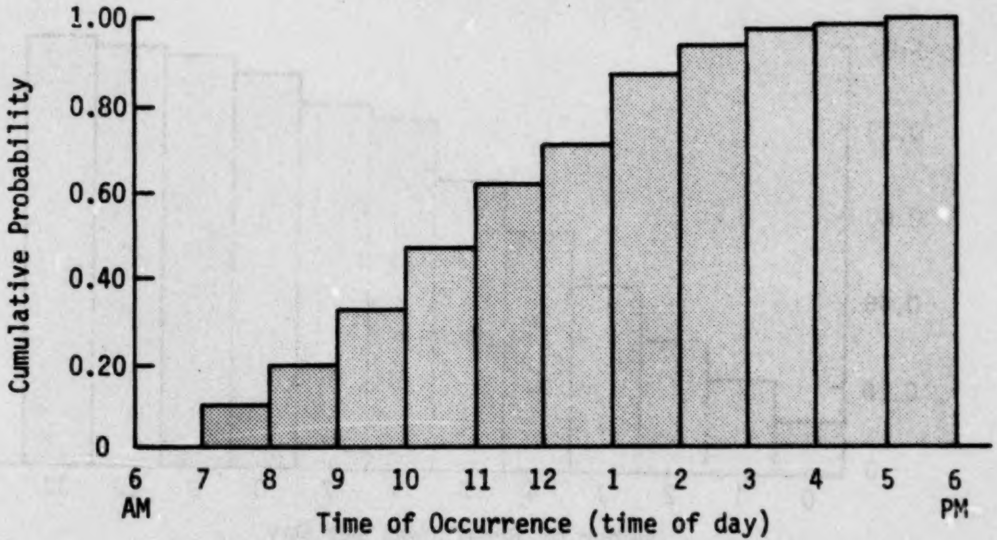
*Developed from data collected on container-train system in Wichita Falls, Texas

Figure I - 13

BREAKDOWN TIMES OF OCCURRENCE*



TRAIN BREAKDOWN TIMES OF OCCURRENCE



CONTAINER TRANSFER VEHICLE BREAKDOWN TIMES OF OCCURRENCE

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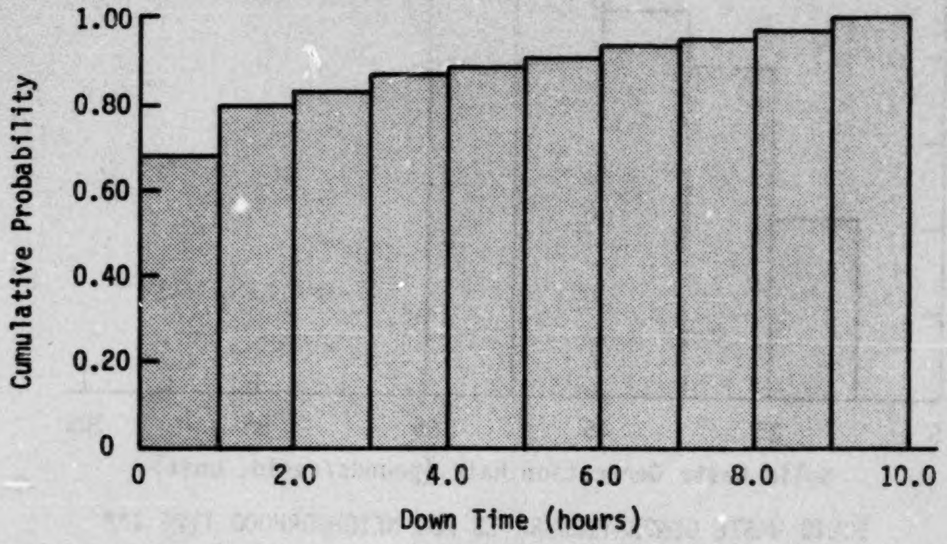
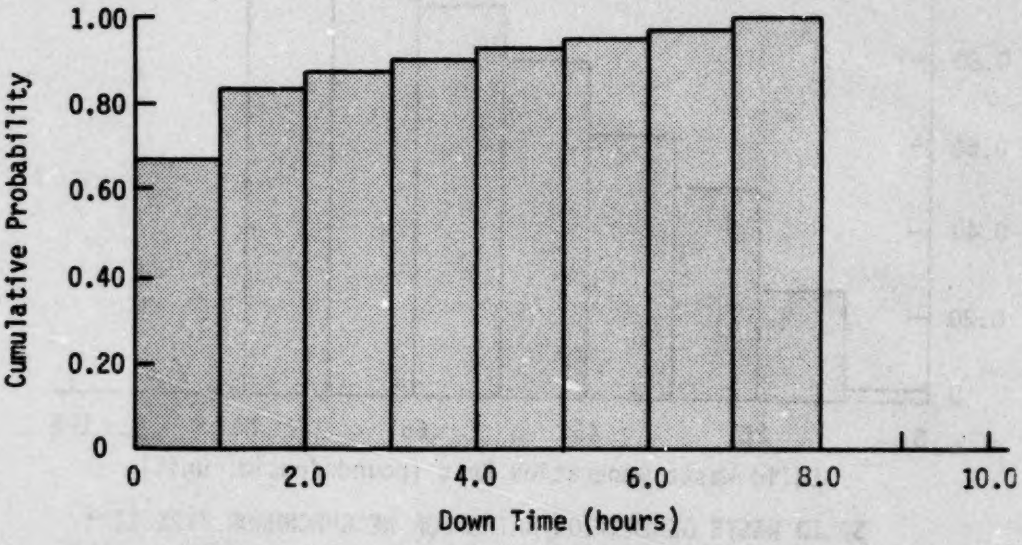
*Developed from data collected on container-train system in Wichita Falls, Texas

Figure I - 14

BREAKDOWN DOWN TIMES*



TRAIN BREAKDOWN DOWN TIMES



CONTAINER TRANSFER VEHICLE BREAKDOWN DOWN TIMES

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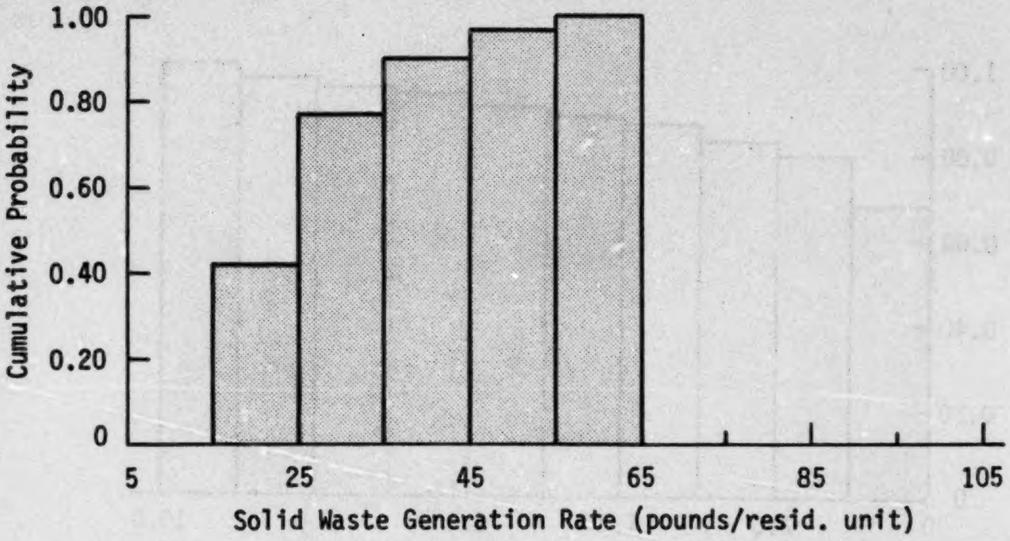
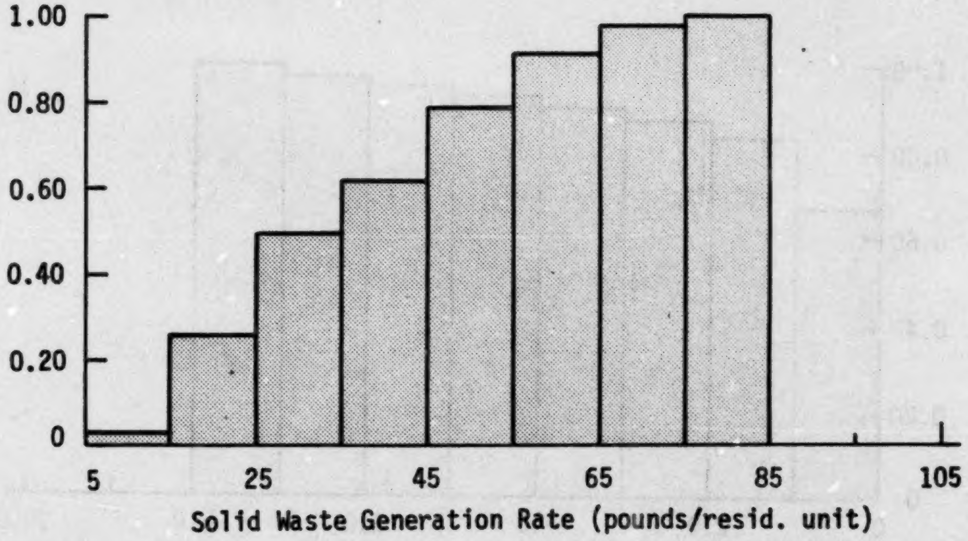
*Developed from data collected on container-train system in Wichita Falls, Texas

Figure I - 15

RESIDENTIAL SOLID WASTE GENERATION RATES*



SOLID WASTE GENERATION RATES FOR NEIGHBORHOOD TYPE I**
(JUNE, FOUR DAYS SINCE LAST COLLECTION)



SOLID WASTE GENERATION RATES FOR NEIGHBORHOOD TYPE II**
(JUNE, FOUR DAYS SINCE LAST COLLECTION)

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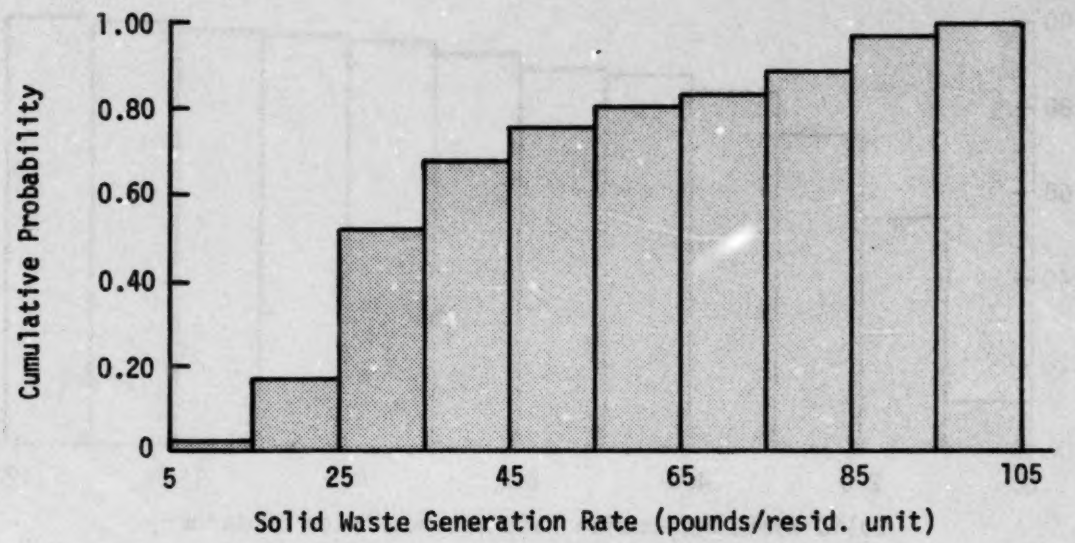
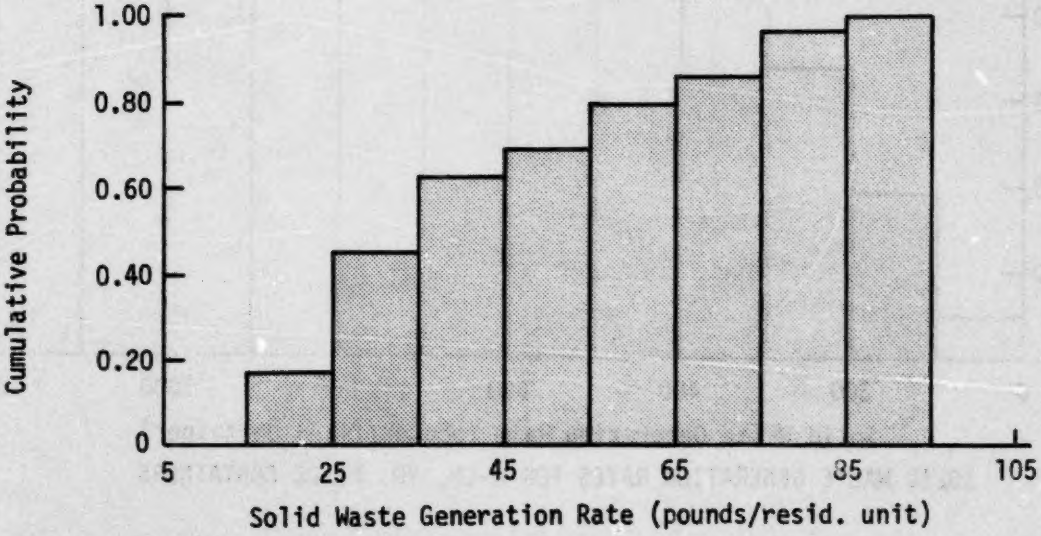
*Developed from data collected in Wichita Falls, Texas

**Neighborhood Type	Average Per Residential Unit Floor Area	Persons
I	≤ 1200	3.0
II	≤ 1200	3.0
III	> 1200	3.0
IV	> 1200	3.0

Figure I - 16



SOLID WASTE GENERATION RATES FOR NEIGHBORHOOD TYPE III**
(JUNE, FOUR DAYS SINCE LAST COLLECTION)



SOLID WASTE GENERATION RATES FOR NEIGHBORHOOD TYPE IV**
(JUNE, FOUR DAYS SINCE LAST COLLECTION)

Figure I - 17

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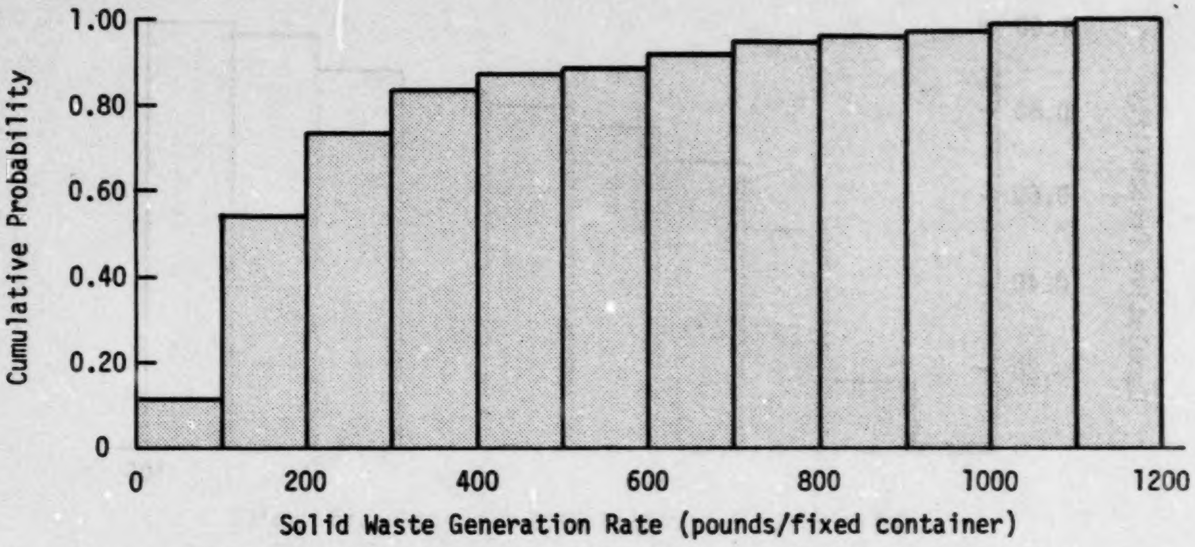
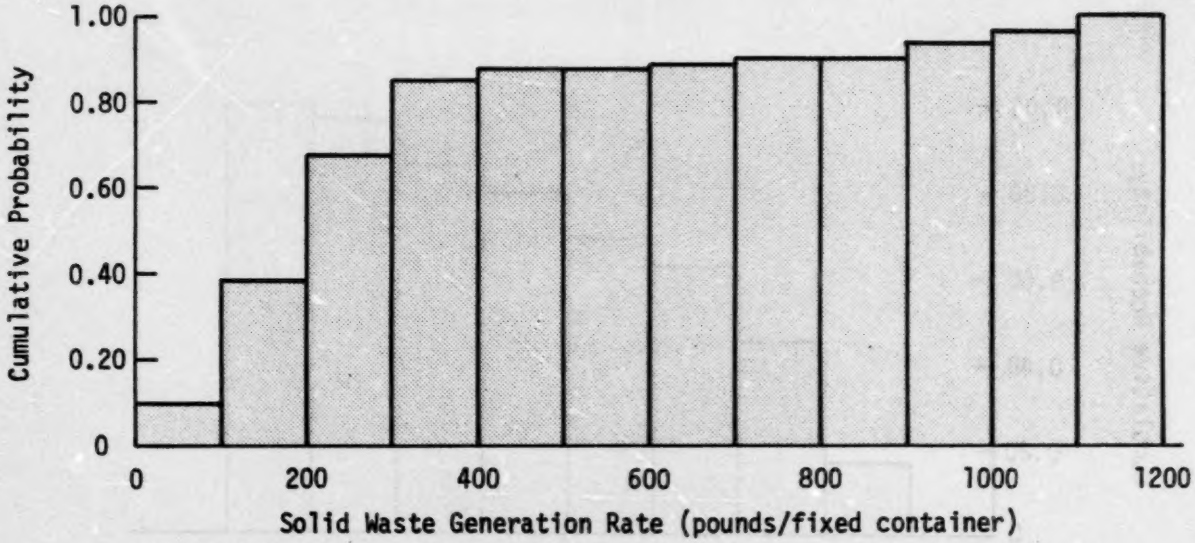
COMMERCIAL SOLID WASTE GENERATION RATES*



SOLID WASTE GENERATION RATES FOR 3-CU. YD. FIXED CONTAINERS



SOLID WASTE GENERATION RATES FOR 4-CU. YD. FIXED CONTAINERS

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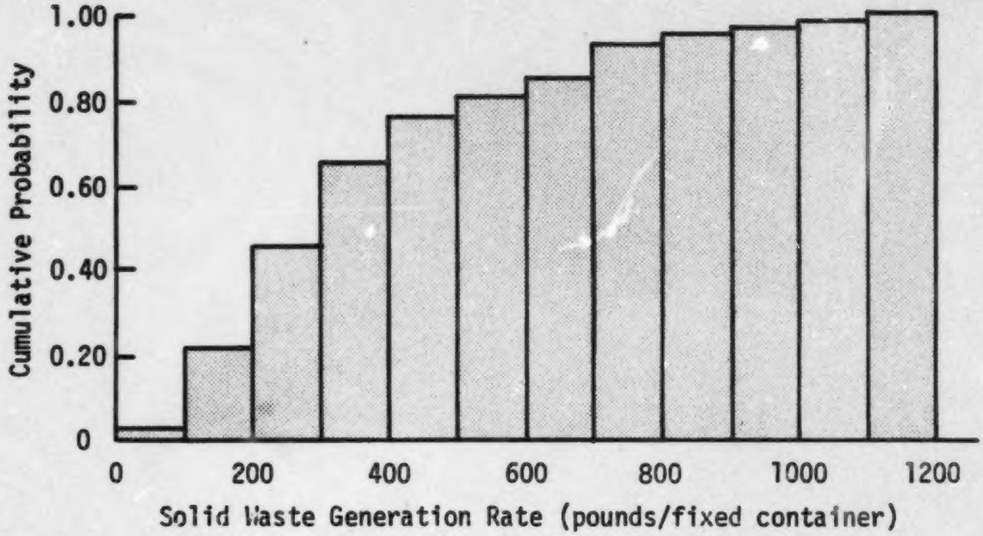
*Developed from data collected in Wichita Falls, Texas

Figure I - 18

COMMERCIAL SOLID WASTE GENERATION RATES (CONT'D).



SOLID WASTE GENERATION RATES FOR 8-CU. YD. FIXED CONTAINERS

Figure I - 19

APPENDIX II

DATA DECK CARD FORMATS

DATA SET 1 - SIMULATION PARAMETERS

Card Cols.	Data	Fortran Format Code
	Data Control Card 1	
1-3	card code (001)	I3
5-68	simulation identification	16A4
	Data Control Card 2	
1-3	card code (002)	I3
5-6	no. of simulation iterations (.GE. 1 and .LE. 10)	I2
8-10	report number	I3

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DATA SET 2 - COLLECTION DATE

Card Cols.	Data	Fortran Format Code
	Data Control Card	
1-3	card code (003)	I3
5-6	month of the year (1 - Jan., 2 - Feb., etc.)	I2
7	no. of days since last collection (1 - 3 days, 2 - 4 days)	I1

DATA SET 3 - STREET NETWORK AREAS

Card Cols.	Data	Fortran Format Code
	Data Control Card	
1-3	card code (011)	I3
5-8	no. of street network areas (.GE. 1 and .LE. 6)	I4
	Data Cards (1 card per permutation of st. network areas taken 2 at a time)	
1-3	card code (012)	
5	street-network-area no. of area I (.GE. 1 and .LE. the no. of street network areas)	I1
6	street-network area no. of area J (.GE. 1 and .LE. the no. of street network areas; and .NE. that of area I)	I1
7	sign of x coordinate of node at which area I is exited on trip from area I to area J (blank - positive, minus - negative)	F9.0
8-15	x coordinate of node at which area I is exited on trip from area I to area J (feet)	
16	sign of y coordinate of node at which area I is exited on trip from area I to area J (blank - positive, minus - negative)	F9.0
17-24	y coordinate of node at which area I is exited on trip from area I to area J (feet)	
25	sign of x coordinate of node at which area J is entered on trip from area I to area J (blank - positive, minus - negative)	F9.0
26-33	x coordinate of node at which area J is entered on trip from area I to area J (feet)	
34	sign of y coordinate of node at which area J is entered on trip from area I to area J (blank - positive, minus - negative)	F9.0
35-42	y coordinate of node of which area J is entered on trip from area I to area J (feet)	
43-48	travel distance between exit node of area I and entrance node of area J on trip from area I to area J (feet; .GE. 0)	F6.0

DATA SET 4 - HEADQUARTERS

Card Cols.	Data	Fortran Format Code
	Data Control Card	
1-3	card code (021)	I3
5-8	no. of headquarters (.GE. 1 and .LE. 9)	I4
	Data Cards (1 per headquarters)	
1-3	card code (022)	I3
5	ID no. of headquarters (.GE. 1 and .LE. the no. of headquarters)	I1
6	sign of x coordinate of headquarters (blank - positive, minus - negative)	F9.0
7-14	x coordinate of headquarters (feet)	
15	sign of y coordinate of headquarters (blank - positive, minus - negative)	F9.0
16-23	y coordinate of headquarters (feet)	
24	street-network-area no. of headquarters (.GE. 1 and .LE. the no. of street network areas)	I1

DATA SET 5 - DISPOSAL SITES

Card Cols.	Data	Fortran Format Code
	Data Control Card	
1-3	card code (031)	I3
5-8	no. of disposal sites (.GE. 1 and .LE. 9)	I4
	Data Cards (1 per disposal site)	
1-3	card code (032)	I3
5	ID no. of disposal site (.GE. 1 and .LE. the no. of disposal sites)	I1
6	sign of x coordinate of disposal site (blank - positive, minus - negative)	F9.0
7-14	x coordinate of disposal site (feet)	
15	sign of y coordinate of disposal site (blank - positive, minus - negative)	F9.0
16-23	y coordinate of disposal site (feet)	
24	street-network-area no. of disposal site (.GE. 1 and .LE. the no. of street network areas)	I1
25	no. of scales at disposal site (.GE. 0 and .LE. 9)	I1
26-27	no. of dumping channels at disposal site (.GE. 1 and .LE. 20)	I2

DATA SET 6 - RESIDENTIAL COLLECTION ROUTE

Card Cols.	Data	Fortran Format Code
	Data Control Card	
1-3	card code (041)	I3
5-8	no. of links in residential collection route (.GE. 0 and .LE. 5000)	I4
9-14	node no. at which residential collection route begins (ANODE)	I6
15	sign of x coordinate of ANODE (blank - positive, minus - negative)	F9.0
16-23	x coordinate of ANODE (feet)	
24	sign of y coordinate of ANODE (blank - positive, minus - negative)	F9.0
25-32	y coordinate of ANODE (feet)	
33	street-network-area no. of ANODE (.GE. 1 and .LE. the no. of street network areas)	I1
	Data Cards (1 per link)	
1-3	card code (042)	I3
5-8	sequence no. of link (.GE. 1 and .LE. the no. of links; and .GT. that of the preceding link and .LT. that of the following link)	I4
9-14	node no. at which link ends (BNODE)	I6
15	sign of x coordinate of BNODE (blank - positive, minus - negative)	F9.0
16-23	x coordinate of BNODE (feet)	
24	sign of y coordinate of BNODE (blank - positive, minus - negative)	F9.0
25-32	y coordinate of BNODE (feet)	
33	street-network-area no. of BNODE (.GE. 1 and .LE. the no. of street network areas)	I1
34-37	length of link (feet; .GT. 0)	F4.0
38-40	no. of residential units on link (.GE. 0)	F3.0
41-43	average no. of persons per residential unit on link (.GT. 0 if no. of residential units on link is .GT. 0)	F3.1
44-49	average floor area per residential unit on link (sq. ft.; .GT. 0 if no. of residential units on link is .GT. 0)	F6.0
50-54	average income per residential unit on link (dollars; .GT. 0 if no. of residential units on link is .GT. 0)	F5.0
55-58	no. of residential units on link that receive carry-out service (.GE. 0 and .LE. the no. of residential units on the link)	I4

DATA SET 6 - (Continued)

Card Cols.	Data	Fortran Format Code
	Data Cards (Continued) (1 per link)	
59	type of carry-outs (1 - carry-out distance .LE. 60 ft., 2 - carry-out distance .GT. 60 ft. and .LE. 100 ft., 3 - carry-out distance .GT. 100 ft.)	I1
60	link code (1 - street with two-side collection, 2 - street with one-side collection, 3 - alley with two-side collection, 4 - alley with one-side collection)	I1
61	link surface (1 - paved, 2 - unpaved)	I1

(147)

DATA SET 7 - COMMERCIAL COLLECTION ROUTE

Card Cols.	Data	Fortran Format Code
	Data Control Card	
1-3	card code (051)	I3
5-8	no. of collection units in commercial collection route (.GE. 0 and .LE. 500)	I4
	Data Cards (1 per collection unit)	
1-3	card code (052)	I3
5-8	sequence no. of collection unit (.GE. 1 and .LE. the no. of collection units; and .GT. that of the preceding collection unit and .LT. that of the following collection unit)	I4
9-14	node no. at which collection unit is located (NODE)	I6
15	sign of x coordinate of NODE (blank - positive, minus - negative)	F9.0
16-23	x coordinate of NODE (feet)	
24	sign of y coordinate of NODE (blank - positive, minus - negative)	F9.0
25-32	y coordinate of NODE (feet)	
33	street-network-area no. of NODE (.GE. 1 and .LE. the no. of street network areas)	I1
34-35	no. of fixed containers in collection unit (.GT. 0)	I2
36	size of fixed containers in collection unit (1 - 3 cu. yd., 2 - 4 cu. yd., 3 - 8 cu. yd.)	I1

DATA SET 8 - RESIDENTIAL COLLECTION SYSTEM

Card Cols.	Data	Fortran Format Code
	Data Control Card 1	
1-3	card code (060)	I3
5	type of residential collection system (0 - no residential collection system, 1 - container-train system, 2 - packer-truck system, 3 - alley/street-container system, 4 - mechnaical-bag-retreiver system)	I1
	Data Control Card 2 - Container-Train System	
1-3	card code (061)	I3
5-8	no. of trains (.GE. 1 and .LE. 50 minus the sum of the no. of container transfer vehicles and the no. of commercial collection vehicles)	I4
9-12	no. of container transfer vehicles (.GE. 1 and .LE. 50 minus the sum of the no. of trains and the no. of commercial collection vehicles)	I4
13	type of residential solid waste containers (1 - cans, 2 - bags)	I1
	Data Control Card 2 - Packer-Truck System	
1-3	card code (081)	I3
5-8	no. of packer trucks (.GE. 1 and .LE. 50 minus the no. of commercial collection vehicles)	I4
9	type of residential solid waste containers (1 - cans, 2 - bags)	I1
	Data Control Card 2 - Alley/Street-Container System	
1-3	card code (091)	I3
5-8	no. of collection vehicles(.GE. 1 and .LE. 50 minus the no. of commercial collection vehicles)	I4
10-12	no. of residential units per alley/street container (.GT. 1.0)	F3.1
	Data Control Card 2 - Mechanical-Bag-Retriever System	
1-3	card code (101)	I3
5-8	no. of collection vehicles (.GE. 1 and .LE. 50 minus the no. of commercial collection vehicles)	I4

***Note:** There is not a Data Control Card 2 if there is not a residential collection system.

DATA SET 8 - (Continued)

Card Cols.	Data	Fortran Format Code
	Data Cards - Container-Train System	
	● **Train Data Cards** (1 per train)	
1-3	card code (062)	I3
5-6	ID no. of train (.GE. 1 and .LE. the no. of trains)	I2
7-12	capacity of train (pounds; .GE. 1000 lbs.)	I6
13	no. of containers in train (1, 2, 3, 4, or 5)	I1
14	size of train's crew (no. of men; 1, 2, or 3)	I1
15-17	ID no. of train's container transfer vehicle (.GT. the no. of trains and .LE. the sum of the no. of trains and the no. of container transfer vehicles)	I3
18	ID no. of train's headquarters (.GE. 1 and .LE. the no. of headquarters)	I1
	● **Container-Transfer-Vehicle Data Cards** (1 per container transfer vehicle)	
1-3	card code (072)	I3
5-7	ID no. of container transfer vehicle (.GT. the no. of trains and .LE. the sum of the no. of trains and the no. of container transfer vehicles)	I3
8-13	capacity of container transfer vehicle (pounds; .GE. to 5000 lbs.)	I6
14	size of container transfer vehicle's crew (no. of men; 1 or 2)	I1
15	ID no. of container transfer vehicle's headquarters (.GE. 1 and .LE. the no. of headquarters)	I1
16	ID no. of container transfer vehicle's disposal site (.GE. 1 and .LE. the no. of disposal sites)	I1
	Data Cards - Packer-Truck or Alley/Street-Container System (1 per collection vehicle)	
1-3	card code (082 - packer-truck system, 092 - alley/street-container system)	I3
5-7	ID no. of collection vehicle (.GE. 1 and .LE. the no. of residenital collection vehicles)	I3
8-13	capacity of collection vehicle (pounds; .GE. 5000 lbs.)	I6
14	size of collection vehicle's crew (no. of men; 1, 2, or 3)	I1
15	ID no. of collection vehicle's headquarters (.GE. 1 and .LE. the no. of headquarters)	I1
16	ID no. of collection vehicle's disposal site (.GE. 1 and .LE. the no. of disposal sites)	I1

DATA SET 8 - (Continued)

Card Cols.	Data	Fortran Format Code
	Data Cards - Mechanical-Bag-Retriever System (1 per collection vehicle)	
1-3	card code (102)	I3
5-7	ID no. of collection vehicle (.GE. 1 and .LE. the no. of residential collection vehicles)	I3
8-13	capacity of collection vehicle (pounds; .GE. 5000 lbs.)	I6
14	ID no. of collection vehicle's headquarters (.GE. 1 and .LE. the no. of headquarters)	I1
15	ID no. of collection vehicle's disposal site (.GE. 1 and .LE. the no. of disposal sites)	I1

DATA SET 9 - RESIDENTIAL COLLECTION ROUTE ASSIGNMENTS*

Card Cols.	Data	Fortran Format Code
	Data Control Card	
1-3	card code (111)	I3
5-8	no. of residential collection route assignments (.EQ. the no. of residential collection vehicles; except in the case of a container-train system, .EQ. the no. of trains)	I4
	Data Cards (1 per residential collection route assignment)	
1-3	card code (112)	I3
5-7	ID no. of collection vehicle (.GE. 1 and .LE. the no. of residential collection vehicles)	I3
8-11**	sequence no. of first link of collection vehicle's assigned route (.GE. 1 and .LE. the no. of links in the residential collection route; and not in between those of the first and last links of another collection vehicle's assigned route)	I4
12-15**	sequence no. of last link of collection vehicle's assigned route (.GE. 1 and .LE. the no. of links in the residential collection route; and not in between those of the first and last links of another collection vehicle's assigned route)	I4

*Note: Data Set 9 is not part of the data deck if there is not a residential collection system.

**Note: Sequence no. of first link of a collection vehicle's assigned route must be less than that of the last link of its assigned route.

DATA SET 10 - COMMERCIAL COLLECTION SYSTEM

Card Cols.	Data	Fortran Format Code
	Data Control Card 1	
1-3	card code (120)	I3
5	type of commercial collection system (0 - no commercial collection system, 1 - container-transfer-vehicle system, 2 - packer-truck system)	I1
	Data Control Card 2*	
1-3	card code (121 - container-transfer-vehicle system, 131 - packer-truck system)	I3
5-8	no. of collection vehicles (.GE. 1 and .LE. 50 minus the no. of residential collection vehicles; if the residential collection system is a container-train system, .EQ. 0 if the commercial collection system is a container-transfer-vehicle system composed entirely of container transfer vehicles which are also part of the container-train system)	I4
	Data Cards (1 per collection vehicle)	
1-3	card code (122 - container-transfer-vehicle system, 132 - packer-truck system)	I3
5-7	ID no. of collection vehicle (.GT. the no. of residential collection vehicles and .LE. the sum of the no. of residential collection vehicles and the no. of commercial collection vehicles)	I3
8-13	capacity of collection vehicle (pounds; .GE. 5000 lbs.)	I6
14	size of collection vehicle's crew (no. of men; 1 or 2 for a container transfer vehicle and 1, 2, or 3 for a packer truck)	I1
15	ID no. of collection vehicle's headquarters (.GE. 1 and .LE. the no. of headquarters)	I1
16	ID no. of collection vehicle's disposal site (.GE. 1 and .LE. the no. of disposal sites)	I1

*__Note__: There is not a Data Control Card 2 if there is not a commercial collection system.

DATA SET 11 - COMMERCIAL COLLECTION ROUTE ASSIGNMENTS*

Card Cols.	Data	Fortran Format Code
	Data Control Card	
1-3	card code (141)	I3
5-8	no. of commercial route assignments (.EQ. the no. of commercial collection vehicles; except in the case where the residential collection system is a container-train system, .GE. the no. of commercial collection vehicles and .LE. the sum of the no. of commercial collection vehicles and the no. of container transfer vehicles in the container-train system)	I4
	Data Cards (1 per commercial collection route assignment)	
1-3	card code (142)	I3
5-7	ID no. of collection vehicle (.GT. the no. of residential collection vehicle, or if the residential collection system is a container-train system .GT. the no. of trains: and .LE. the sum of the no. of residential collection vehicle and the no. of commercial collection vehicles)	I3
8-11**	sequence no. of first collection unit of collection vehicle's assigned route (.GE. 1 and .LE. the no. of collection units in the commercial collection route; and not in between those of the first and last collection units of another collection vehicle's assigned route)	I4
12-15**	sequence no. of last collection unit of collection vehicle's assigned route (.GE. 1 and .LE. the no. of collection units in the commercial collection route; and not in between those of the first and last collection units of another collection vehicle's assigned route)	I4

*Note: Data Set 11 is not part of the data deck if there is not a commercial collection system.

**Note: Sequence no. of first collection unit of a collection vehicle's assigned route must be less than that of the last collection unit of its assigned route.

DATA SET 12 - OPTIONAL PERFORMANCE CHARACTERISTICS*

Card Cols.	Data	Fortran Format Code
	● **Data Subset 12-1: Optional Departure Times** (time of day in minutes)	
	Data Control Card	
1-3	card code (171)	I3
5-8	no. of cumulative histograms of departure times to be input (.GE. 0 and .LE. the product of 3 times the no. of headquarters)	I4
	Data Cards (1 per cumulative histogram of departure times to be input)	
1-3	card code (172)	I3
4	type of collection vehicle (1 - residenital, 2 - residential container transfer vehicle, 3 - commercial)	I1
5	ID no. of headquarters (.GE. 1 and .LE. the no. of headquarters)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2
	● **Data Subset 12-2: Optional Collection Times Per Residential Unit** (minutes per residential unit)	
	Data Control Card	
1-3	card code (181)	I3
5-8	no. of cumulative histograms of collection times per residential unit to be input (.GE. 0 and .LE. 24)	I4
	Data Cards (1 per cumulative histogram of collection times per residential unit to be input)	
1-3	card code (182)	I3
4	crew size (no. of men; 1, 2, or 3)	I1
5	link code (1 - street with two-side collection, 2 - street with one-side collection, 3 - alley with two-side collection, 4 - alley with one-side collection)	I1
6	link surface (1 - paved, 2 - unpaved)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2

DATA SET 12 - (Continued)

Card Cols.	Data	Format Format Code
	● **Data Subset 12-3: Optional Additional Collection Times Per Carry-Out** (minutes per carry-out)	
	Data Control Card	
1-3	card code (191)	I3
5-8	no. of cumulative histograms of additional collection times per carry-out to be input (.GE. 0 and .LE. 36)	I4
	Data Cards (1 per cumulative histogram of additional collection times per carry-out to be input)	
1-3	card code (192)	I3
4	crew size (no. of men; 1, 2, or 3)	I1
5	link code (1 - street with two-side collection, 2 - street with one-side collection, 3 - alley with two-side collection, 4 - alley with one-side collection)	I1
7	type of carry-out (1 - carry-out distance .LE. 60 ft., 2 - carry-out distance .GT. 60 ft. and .LE. 100 ft., 3 - carry-out distance .GT. 100 ft.)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2
	● **Data Subset 12-4: Optional Non-Collection Speeds** (feet per minute)	
	Data Control Card	
1-3	card code (201)	I3
5-8	no. of cumulative histograms of non-collection speeds to be input (.GE. 0 and .LE. 16)	I4
	Data Cards (1 per cumulative histogram of non-collection speeds to be input)	
1-3	card code (202)	I3
5	link surface (1 - paved, 2 - unpaved)	I1
6	collection code (1 - non-collection link, 2 - collection link)	I1
7	distance code (1 - link distance .LE. to DNCS1, 2 - link distance .GT. DNCS1 and .LE. DNCS2, 3 - link distance .GT. DNCS2 and .LE. DNCS3, 4 - link distance .GT. DNCS 3)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2

DATA SET 12 - (Continued)

Card Cols.	Data	Fortran Format Code

● Data Subset 12-5: Optional Container Dump Times (minutes per container)

Data Control Card

Card Cols.	Data	Fortran Format Code
1-3	card code (211)	I3
5-8	no. of cumulative histograms of container dump times to be input (.GE. 0 and .LE. 4)	I4

Data Cards
(1 per cumulative histogram of container dump times to be input)

Card Cols.	Data	Fortran Format Code
1-3	card code (212)	I3
4	type of container (1 - 3 cu. yd., 2 - 4 cu. yd., 3 - 8 cu. yd., 4 - train)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2

● Data Subset 12-6: Optional Travel Speeds (feet per minute)

Data Control Card

Card Cols.	Data	Fortran Format Code
1-3	card code (221)	I3
5-8	no. of cumulative histograms of travel speeds to be input (.GE. 0 and .LE. 24)	I4

Data Cards
(1 per cumulative histogram of travel speeds to be input)

Card Cols.	Data	Fortran Format Code
1-3	card code (222)	I3
4	type of collection vehicle (1 - train, 2 - residential packer truck, 3 - alley/street-container collection vehicle, 4 - mechanical bag retriever, 5 - container transfer vehicle, 6 - commercial packer truck)	I1
5	distance code (1 - travel distance .LE. DTS1, 2 - travel distance .GT. DTS1 and .LE. DTS2, 3 - travel distance .GT. DTS2 and .LE. DTS3, 4 - travel distance .GT. DTS3)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2

DATA SET 12 - (Continued)

Card Cols.	Data	Fortran Format Code
	● **Data Subset 12-7: Optional Weighing Times** (minutes)	
	Data Control Card	
1-3	card code (231)	I3
5-8	no. of cumulative histograms of weighing times to be input (.GE. 0 and .LE. the product of 6 times the no. of disposal sites)	I4
	Data Cards (1 per cumulative histogram of weighing time to be input)	
1-3	card code (232)	I3
4	type of collection vehicle (1 - train, 2 - residential packer truck, 3 - alley/street-container collection vehicle, 4 - mechanical bag retriever, 5 - container transfer vehicle, 6 - commercial packer truck)	I1
5	ID no. of disposal site (.GE. 1 and .LE. the no. of disposal sites)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2
	● **Data Subset 12-8: Optional Dump Times** (minutes)	
	Data Control Card	
1-3	card code (241)	I3
5-8	no. of cumulative histograms of dump times to be input (.GE. 0 and .LE. the produce of 6 times the no. of disposal sites)	I4
	Data Cards (1 per cumulative histogram of dump times to be input)	
1-3	card code (242)	I3
4	type of collection vehicle (1 - train, 2 - residential packer truck, 3 - alley/street-container collection vehicle, 4 - mechanical bag retriever, 5 - container transfer vehicle, 6 - commercial packer truck)	I1
5	ID no. of disposal site (.GE. 1 and .LE. the no. of disposal sites)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2

DATA SET 12 - (Continued)

● Data Subset 12-9: Optional Breakdown Frequencies (no. of breakdowns per day per collection vehicle)

Data Control Card

Card Cols.	Data	Fortran Format Code
1-3	card code (251)	I3
5-8	no. of cumulative histograms of breakdown frequencies to be input (.GE. 0 and .LE. 6)	I4

Data Cards

(1 per cumulative histogram of breakdown frequencies to be input)

Card Cols.	Data	Fortran Format Code
1-3	card code (252)	I3
4	type of collection vehicle (1 - train, 2 - residential packer truck, 3 - alley/street-container collection vehicle, 4 - mechanical bag retriever, 5 - container transfer vehicle, 6 - commercial packer truck)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2

● Data Subset 12-10: Optional Breakdown Times of Occurrence (time of day in minutes)

Data Control Card

Card Cols.	Data	Fortran Format Code
1-3	card code (261)	I3
5-8	no. of cumulative histograms of breakdown times of occurrence to be input (.GE. 0 and .LE. 6)	I4

Data Cards

(1 per cumulative histogram of breakdown times of occurrence to be input)

Card Cols.	Data	Fortran Format Code
1-3	card code (262)	I3
4	type of collection vehicle (1 - train, 2 - residential packer turck, 3 - alley/street-container vehicle, 4 - mechanical bag retriever, 5 - container transfer vehicle, 6 - commercial packer truck)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2

DATA SET 12 - (Continued)

Card Cols.	Data	Fortran Format Code
	● **Data Subset 12-11: Optional Breakdown Down Times (minutes)**	
	Data Control Card	
1-3	card code (271)	I3
5-8	no. of cumulative histograms of breakdown down times to be input (.GE. 0 and .LE. 6)	I4
	Data Cards (1 per cumulative histogram of breakdown down times to be input)	
1-3	card code (272)	I3
4	type of collection vehicle (1 - train, 2 - residential packer turck, 3 - alley/street-container collection vehicle, 4 - mechanical bag retriever, 5 - container transfer vehicle, 6 - commerical packer truck)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2
	● **Data Subset 12-12: Optional Breakdown Replacement Times (minutes)**	
	Data Control Card	
1-3	card code (281)	I3
5-8	no. of cumulative histograms of breakdown replacement times to be input (.GE. 0 and .LE. 6)	I4
	Data Cards (1 per cumulative histogram of breakdown replacement times to be input)	
1-3	card code (282)	I3
4	type of collection vehicle (1 - train, 2 - residential packer truck, 3 - alley/street-container collection vehicle, 4 - mechanical bag retriever, 5 - container transfer vehicle, 6 - commercial packer truck)	I1
8-15		F8.0
16-23	cumulative histogram parameters**	F8.0
24-25		F2.0
26-55		10F3.2

DATA SET 12 - (Continued)

* Note: All of the data subsets of Data Set 12 must be included in the data deck, and they must be in sequence. If the no. of cumulative histograms to be input, which is specified on the data control card of a data subset, is zero, the data subset should not contain any data cards.

** Note: The cumulative histogram parameters on the data cards of Data Set 12 are the following:

Data ard Cols.	Cumulative Histogram Parameter	Fortran Format Code
8-15	minimum value of performance characteristic	F8.0
16-23	maximum value of performance characteristic	F8.0
24-25	no. of equal-sized intervals into which range of performance characteristic is divided (.GE. 0 and .LE. 10; if .EQ. 0, minimum value of performance characteristic, which is specified in card columns 8 - 15, is always used by the model as the value of the performance characteristic)	F2.0
26-55	up to 10 3-digit fields for cumulative probabilities associated with upper limits of equal-sized intervals (each cumulative probability .GT. 0 and .LE. 1; the no. of cumulative probabilities .EQ. the no. of equal-sized intervals, and must be input in ascending order with the last one .EQ. 1)	10F3.2

DATA SET 13 - OPTIONAL SOLID WASTE GENERATION RATES*

Card Cols.	Data	Fortran Format Code
	Data Control Card	
1-3	card code (151)	I3
5-8	no. of cumulative histograms of solid waste generation rates to be input (.GE. 0 and .LE. 7)	I4
	Data Cards (1 per cumulative histogram of solid waste generation rates to be input)	
1-3	card code (152)	I3
4	solid waste generation rate code (1 - neighborhood type 1, 2 - neighborhood type 2, 3 - neighborhood type 3, 4 - neighborhood type 4, 5 - 300 cu. yd. fixed container, 6 - 400 cu. yd. fixed container, 7 - 800 cu. yd. fixed container)	I1
8-15	minimum value of solid waste generation rate	F8.0
16-23	maximum value of solid waste generation rate	F8.0
24-25	no. of equal-sized intervals into which range of solid waste generation rate is divided (.GE. 0 and .LE. 10; if .EQ. 0, minimum value of solid waste generation rate, which is specified in card columns 8-15, is always used by the model as the value of the solid waste generation rate)	F2.0
26-55	up to 10 3-digit fields for cumulative probabilities associated with upper limits of equal-sized intervals (each cumulative probability .GT. 0 and .LE. 1; the no. of cumulative probabilities .EQ. the no. of equal-sized intervals, and must be input in ascending order with the last one .EQ. 1)	10F3.2

* Note: Data Set 13 must be included in the data deck. If the no. of cumulative histograms to be input, which is specified on the data control card, is zero, the data set should not contain any data cards.

DATA SET 14 - PRESCHEDULED ACTIVITIES

Card Cols.	Data	Fortran Format Code
	Data Control Card	
1-3	card code (161)	I3
5-8	no. of prescheduled activities (.GE. 0 and .LE. 100)	I4
	Data Cards* (1 per prescheduled activity)	
1-3	card code (162)	I3
5-7	ID no. of collection vehicle involved (.GE. 1 and .LE. the sum of the no. of residential collection vehicles and the no. of commercial collection vehicles)	I3
8-9	sequence no. of prescheduled activity of collection vehicle involved (1 or 2)	I2
10-13	time of occurrence of prescheduled activity (time of day in minutes; .GE. 0 and .LE. 1440)	F4.0
14-17	duration of prescheduled activity (minutes; .GT. 0 and .LE. 240)	F4.0
18-20	distance traveled by collection vehicle involved during prescheduled activity (miles)	F3.1

* Note: Prescheduled activities must be input in order according to collection vehicle ID no. and prescheduled activity sequence no. Each collection vehicle is allowed a maximum of two prescheduled activities. Of two prescheduled activities for a collection vehicle, the one which occurs first has sequence no. 1 and the other has sequence no. 2.

DATA SET 15 - ASSIGNED DEPARTURE TIMES

Card Cols.	Data	Fortran Format Code
	Data Control Card	
1-3	card code (291)	I3
5-8	no. of assigned departure time data cards (.EQ. 0 or .EQ. the no. of headquarters)	I4
	Data Cards*	
1-3	card code (292)	I3
5	ID no. of headquarters (.GE. 1 and .LE. the no. of headquarters)	I1
6-9	departure time of residential collection vehicles other than container transfer vehicles of a container-train system (time of day in minutes; .GE. 0 and .LE. 1440)	F4.0
10-13	departure time of container transfer vehicles of a container-train system (time of day in minutes; .GE. 0 and .LE. to 1440)	F4.0
14-17	departure time of commercial collection vehicles (time of day in minutes; .GE. 0 and .LE. 1440)	F4.0

* Note: Data cards must be input in order according to ID no. of headquarters beginning with headquarters ID no. 1.

APPENDIX III

EDIT CODES

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EDIT CODES

ALL DATA CARDS

A - card code not numeric
B - card code not in sequence
C - card code not valid

CARD CODE: 001

No Edits

CARD CODE: 002

D - no. of iterations not valid

CARD CODE: 003

D - month not valid
E - no. of day since last collection not valid

CARD CODES: 011, 021, 031, 051, 101, 111, 121, 131, 141, 151, 161, 171, 181, 191, 201, 211, 221, 231, 241, 251, 261, 271, 281, 291

D - count not valid

CARD CODE: 012

D - area I not valid
E - area J not valid
F - sign of X coordinate of area I not valid
G - X coordinate of area I not numeric
H - sign of Y coordinate of area I not valid
I - Y coordinate of area I not numeric
J - sign of X coordinate of area J not valid
K - X coordinate of area J not numeric
L - sign of Y coordinate of area J not valid
M - Y coordinate of area J not numeric
N - travel distance not valid

CARD CODE: 022

D - ID no. not valid
E - sign of X coordinate not valid
F - X coordinate not numeric
G - sign of Y coordinate not valid
H - Y coordinate not numeric
I - area no. not valid

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CARD CODE: 032

D - ID no. not valid
E - sign of X coordinate not valid
F - X coordinate not numeric
G - sign of Y coordinate not valid
H - Y coordinate not numeric
I - area no. not valid
J - no. of scales not numeric
K - no. of dumping channels not valid

CARD CODE: 041

D - node no. not numeric
E - sign of X coordinate not valid
F - X coordinate not numeric
G - sign of Y coordinate not valid
H - Y coordinate not numeric
I - area no. not valid
J - no. of links not valid

CARD CODE: 042

D - sequence no. not numeric
E - sequence no. not consecutive
F - sequence no. out of range
G - node no. not numeric
H - sign of X coordinate not valid
I - X coordinate not numeric
J - sign of Y coordinate not valid
K - Y coordinate not numeric
L - area no. not valid
M - length of link not valid
N - no. of residential units not numeric
O - avg. no. of persons per residential unit not numeric
P - avg. floor area per residential unit not numeric
Q - avg. income per residential unit not numeric
R - no. of carry-outs not numeric
S - type of carry-outs not valid
T - no. of residential units not .GE. zero
U - no. of residential units .GT. zero, but avg. no. of persons per residential unit not .GT. zero
V - no. of residential units .GT. zero, but avg. floor area per residential unit not .GT. zero
W - no. of residential units .GT. zero, but avg. income per residential unit not .GT. zero
X - link code not valid
Y - link surface not valid
Z - no. of carry-outs not .LE. no. of residential units

CARD CODE: 052

D - sequence no. not numeric
E - sequence no. not consecutive
F - sequence no. out of range
G - node no. not numeric
H - sign of X coordinate not valid
I - X coordinate not numeric
J - sign of Y coordinate not valid
K - Y coordinate not numeric
L - area no. not valid
M - no. of fixed containers not numeric
N - size of fixed containers not valid

CARD CODE: 060

D - type of system not valid

CARD CODE: 061

D - no. of trains not numeric
E - no. of trains out of range
F - no. of container transfer vehicles not numeric
G - no. of container transfer vehicles out of range
H - type of container not valid

CARD CODE: 062

D - ID no. of train not valid
E - capacity not valid
F - no. of containers not valid
G - crew size not valid
H - ID no. of container transfer vehicle not valid
I - ID no. of headquarters not valid

CARD CODES: 072, 082, 092, 122, 132

D - ID no. of collection vehicle not valid
E - capacity not valid
F - crew size not valid
G - ID no. of headquarters not valid
H - ID no. of disposal site not valid

CARD CODE: 081

D - type of container not valid
E - no. of packer trucks not valid

CARD CODE: 091

D - no. of residential units per alley/street container not valid
E - no. of collection vehicles not valid

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CARD CODE: 102

D - ID no. of collection vehicle not valid
E - capacity not valid
F - ID no. of headquarters not valid
G - ID no. of disposal site not valid

CARD CODE: 112

D - ID no. not numeric
E - ID no. not consecutive
F - ID no. out of range
G - sequence no. of first link not valid
H - sequence no. of last link not valid
I - sequence no. of last link not .GT. sequence no. of first link

CARD CODE: 120

D - type of system not valid

CARD CODE: 142

D - ID no. not numeric
E - ID no. not consecutive
F - ID no. out of range
G - sequence no. of first collection unit not valid
H - sequence no. of last collection unit not valid
I - sequence no. of last collection unit not .GT. sequence no. of first collection unit

CARD CODE: 152

D - solid waste generation rate code not valid
E - minimum value not numeric
F - maximum value not numeric
G - maximum value not .GT. minimum value
H - no. of intervals not valid
I - cumulative probability not valid

CARD CODE: 162

D - ID no. not valid
E - sequence no. not valid
F - time of occurrence not valid
G - duration not valid
H - distance traveled not valid

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CARD CODE: 172

D - type of collection vehicle not valid
E - ID no. of headquarters not valid
F - minimum value not numeric
G - maximum value not numeric
H - maximum value not .GT. minimum value
I - no. of intervals not valid
J - cumulative probability not valid

CARD CODE: 182

D - crew size not valid
E - link code not valid
F - link surface not valid
G - minimum value not numeric
H - maximum value not numeric
I - maximum value not .GT. minimum value
J - no. of intervals not valid
K - cumulative probability not valid

CARD CODE: 192

D - crew size not valid
E - link code not valid
F - type of carry-out not valid
G - minimum value not numeric
H - maximum value not numeric
I - maximum value not .GT. minimum value
J - no. of intervals not valid
K - cumulative probability not valid

CARD CODE: 202

D - link surface not valid
E - collection code not valid
F - distance code not valid
G - minimum value not numeric
H - maximum value not numeric
I - maximum value not .GT. minimum value
J - no. of intervals not valid
K - cumulative probability not valid

CARD CODE: 212

D - type of container not valid
E - minimum value not numeric
F - maximum value not numeric
G - maximum value not .GT. minimum value
H - no. of intervals not valid
I - cumulative probability not valid

CARD CODE: 222

D - type of collection vehicle not valid
E - distance code not valid
F - minimum value not numeric
G - maximum value not numeric
H - maximum value not .GT. minimum value
I - no. of intervals not valid
J - cumulative probability not valid

CARD CODES: 232, 242

D - ID no. of disposal site not valid
E - type of collection vehicle not valid
F - minimum value not numeric
G - maximum value not numeric
H - maximum value not .GT. minimum value
I - no. of intervals not valid
J - cumulative probability not valid

CARD CODES: 252, 262, 272, 282

D - type of collection vehicle not valid
E - minimum value not numeric
F - maximum value not numeric
G - maximum value not .GT. minimum value
H - no. of intervals not valid
I - cumulative probability not valid

CARD CODE: 292

D - ID no. not valid
E - ID no. not consecutive
F - ID no. out of range
G - departure time of residential collection vehicles not valid
H - departure time of container transfer vehicles not valid
I - departure time of commercial collection vehicles not valid

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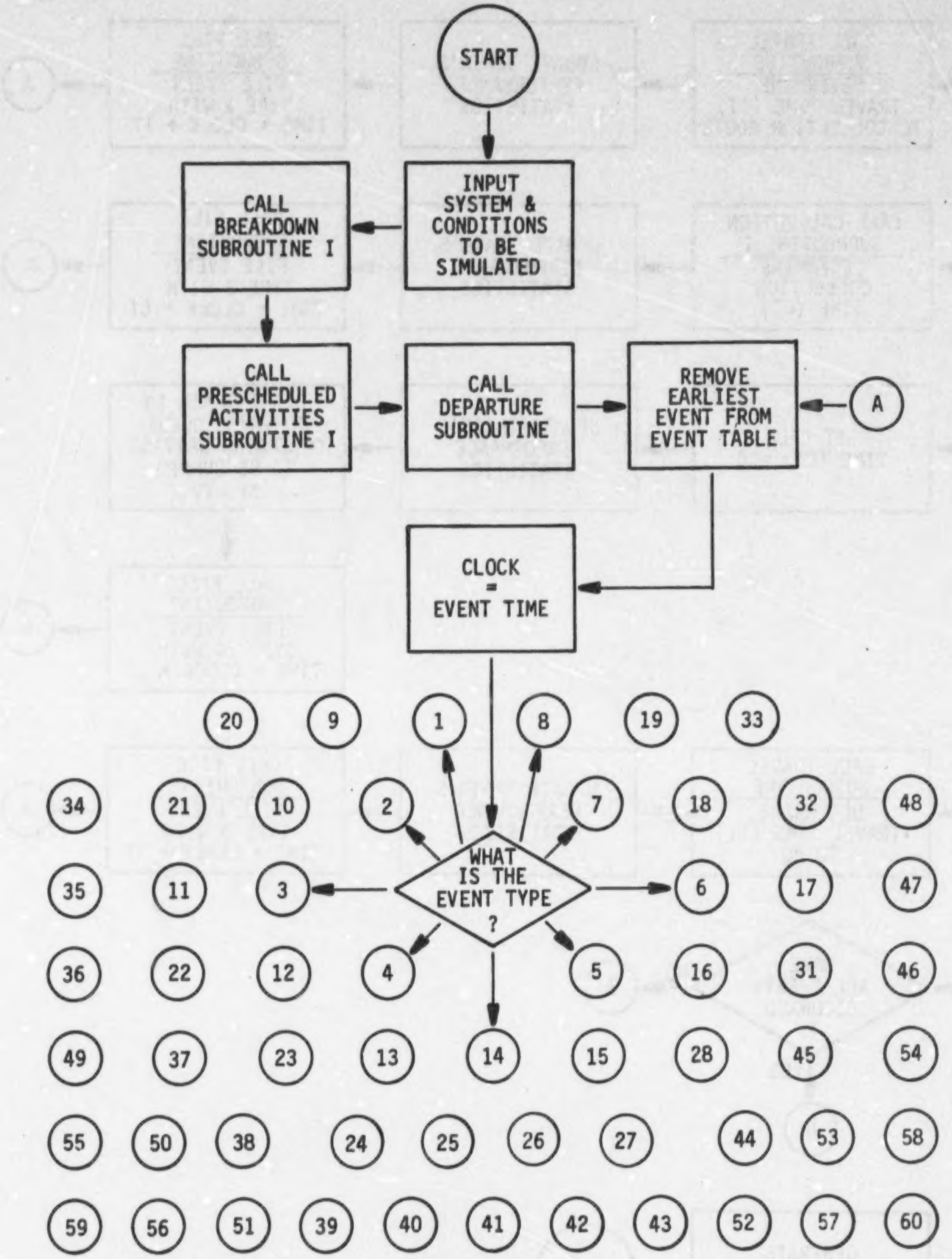
APPENDIX IV

MAIN PROGRAM LOGIC FLOW CHART


START
INPUT SYSTEM & CONDITIONS TO BE SIMULATED
CALL BREAKDOWN SUBROUTINE I
CALL PRESCHEDULED ACTIVITIES SUBROUTINE I
CALL DEPARTURE SUBROUTINE
REMOVE EARLIEST EVENT FROM EVENT TABLE
A
CLOCK = EVENT TIME
WHAT IS THE EVENT TYPE ?
20
9
1
8
19
33
34
21
10
2
7
18
32
48
35
11
3
6
17
47
36
22
12
4
5
16
31
46
49
37
23
13
14
15
28
45
54
55
50
38
24
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60

Figure IV - 1

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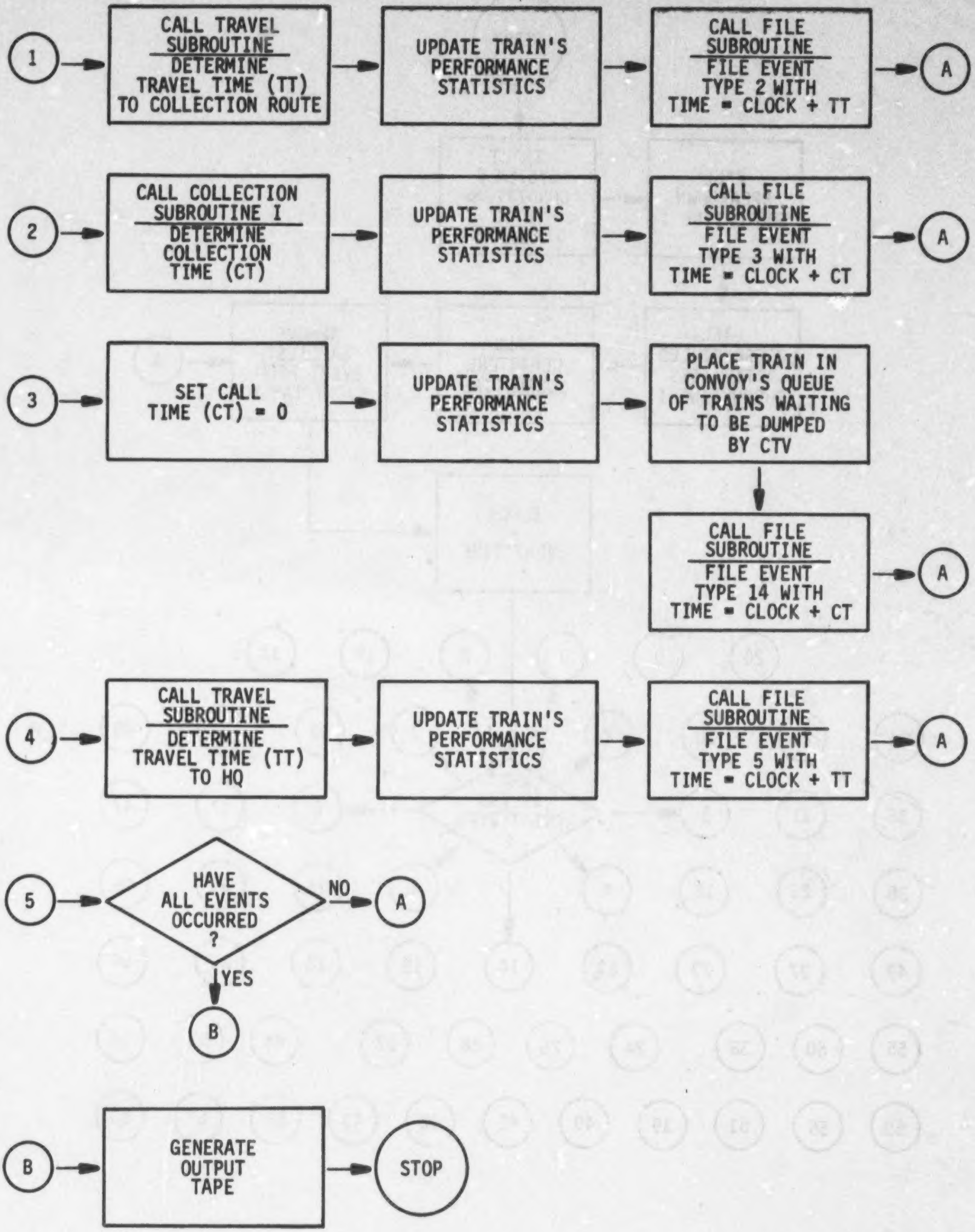
1
CALL TRAVEL SUBROUTINE
DETERMINE TRAVEL TIME (TT) TO COLLECTION ROUTE
UPDATE TRAIN'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE
FILE EVENT TYPE 2 WITH TIME = CLOCK + TT
A
2
CALL COLLECTION SUBROUTINE I
DETERMINE COLLECTION TIME (CT)
UPDATE TRAIN'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE
FILE EVENT TYPE 3 WITH TIME = CLOCK + CT
A
3
SET CALL TIME (CT) = 0
UPDATE TRAIN'S PERFORMANCE STATISTICS
PLACE TRAIN IN CONVOY'S QUEUE OF TRAINS WAITING TO BE DUMPED BY CTV
CALL FILE SUBROUTINE
FILE EVENT TYPE 14 WITH TIME = CLOCK + CT
A
4
CALL TRAVEL SUBROUTINE
DETERMINE TRAVEL TIME (TT) TO HQ
UPDATE TRAIN'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE
FILE EVENT TYPE 5 WITH TIME = CLOCK + TT
A
5
HAVE ALL EVENTS OCCURRED ?
NO
A
YES
B
B
GENERATE OUTPUT TAPE
STOP

Figure IV - 2

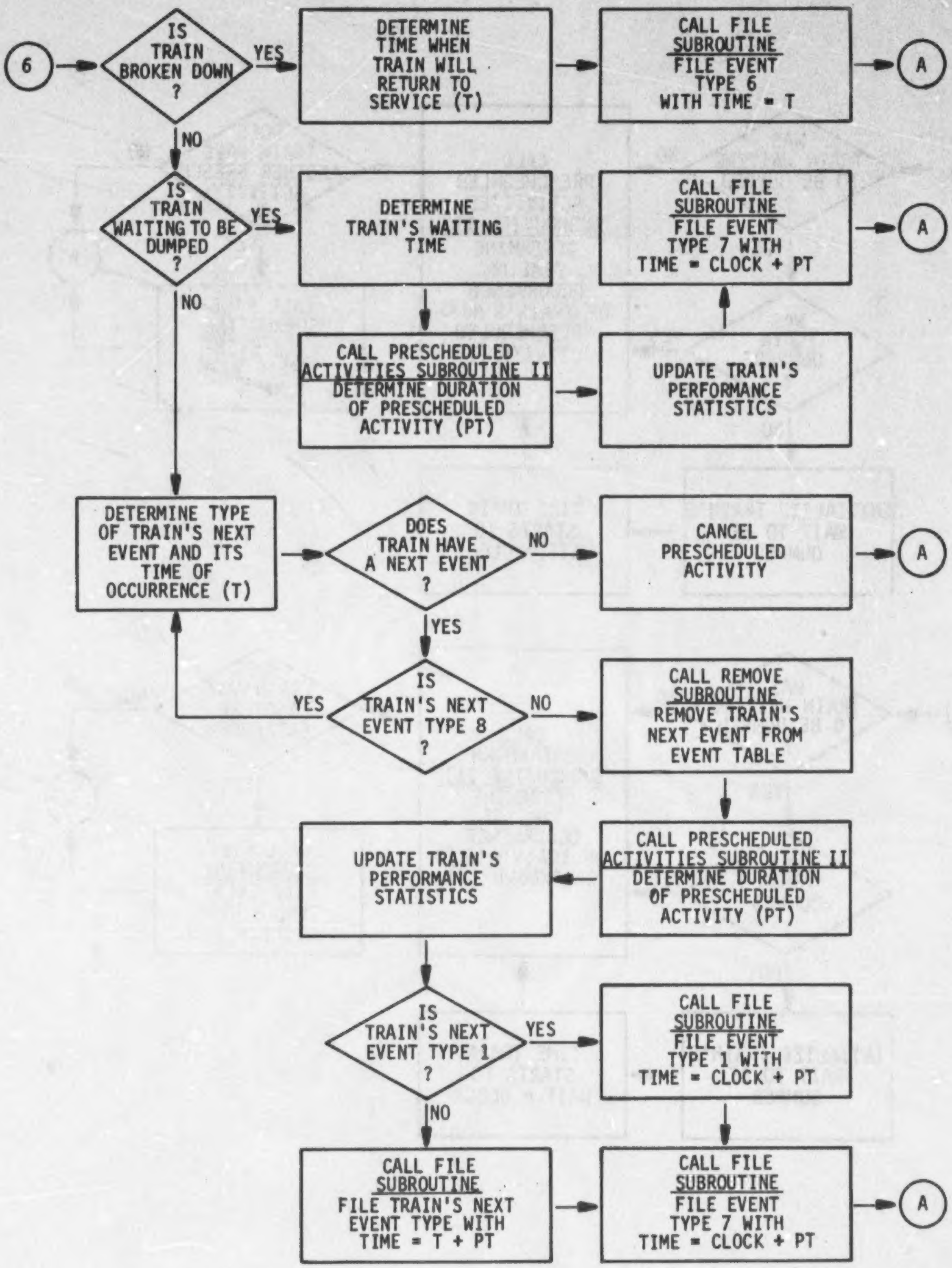
6
IS TRAIN BROKEN DOWN ?
YES
DETERMINE TIME WHEN TRAIN WILL RETURN TO SERVICE (T)
CALL FILE SUBROUTINE
FILE EVENT TYPE 6 WITH TIME = T
A
NO
IS TRAIN WAITING TO BE DUMPED ?
YES
DETERMINE TRAIN'S WAITING TIME
CALL FILE SUBROUTINE
FILE EVENT TYPE 7 WITH TIME = CLOCK + PT
A
NO
CALL PRESCHEDULED ACTIVITIES SUBROUTINE II
DETERMINE DURATION OF PRESCHEDULED ACTIVITY (PT)
UPDATE TRAIN'S PERFORMANCE STATISTICS
DETERMINE TYPE OF TRAIN'S NEXT EVENT AND ITS TIME OF OCCURRENCE (T)
DOES TRAIN HAVE A NEXT EVENT ?
NO
CANCEL PRESCHEDULED ACTIVITY
A
YES
IS TRAIN'S NEXT EVENT TYPE 8 ?
YES
NO
CALL REMOVE SUBROUTINE
REMOVE TRAIN'S NEXT EVENT FROM EVENT TABLE
CALL PRESCHEDULED ACTIVITIES SUBROUTINE II
DETERMINE DURATION OF PRESCHEDULED ACTIVITY (PT)
UPDATE TRAIN'S PERFORMANCE STATISTICS
IS TRAIN'S NEXT EVENT TYPE 1 ?
YES
CALL FILE SUBROUTINE
FILE EVENT TYPE 1 WITH TIME = CLOCK + PT
NO
CALL FILE SUBROUTINE
FILE TRAIN'S NEXT EVENT TYPE WITH TIME = T + PT
CALL FILE SUBROUTINE
FILE EVENT TYPE 7 WITH TIME = CLOCK + PT
A

Figure IV - 3

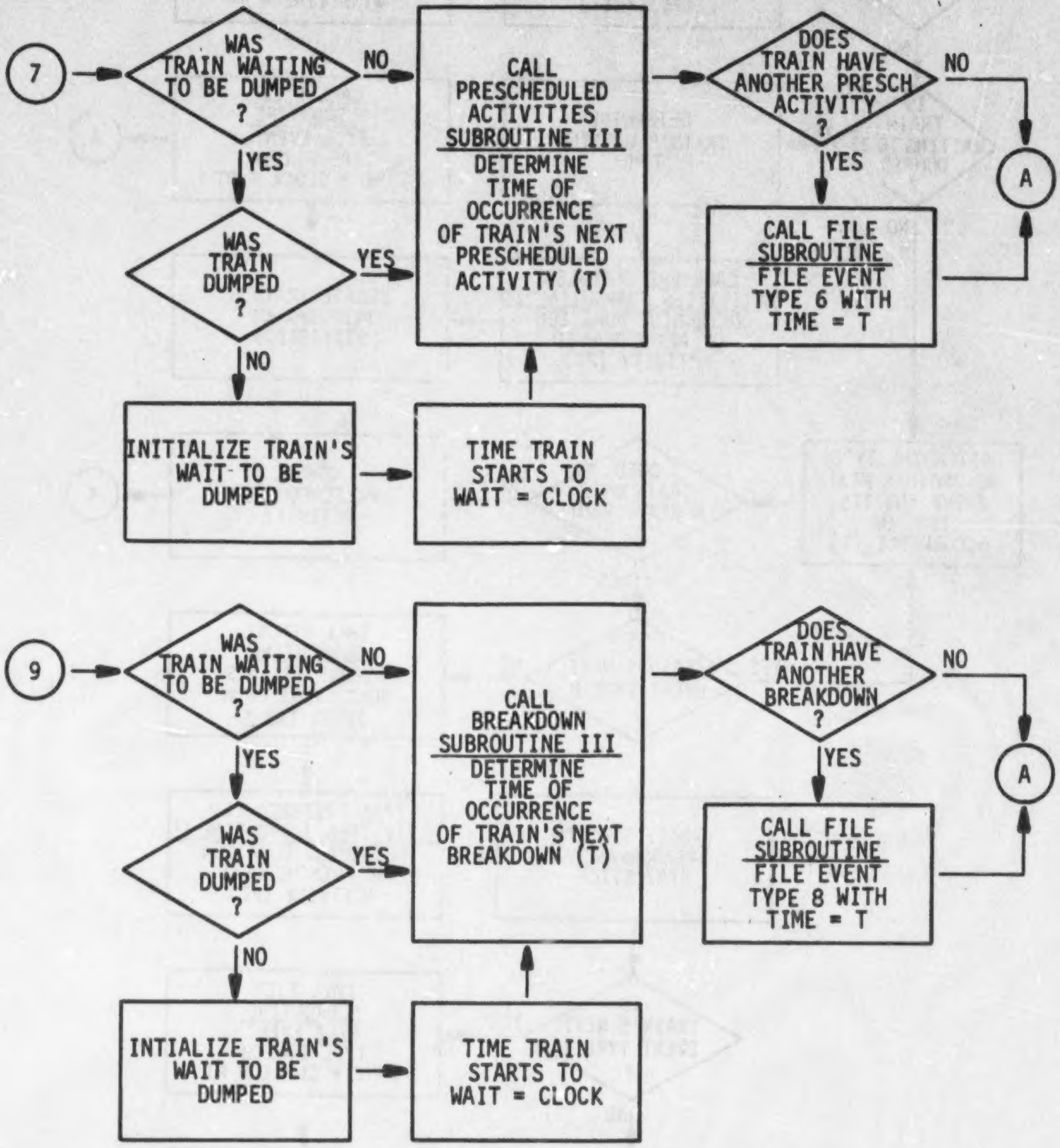
7
WAS TRAIN WAITING TO BE DUMPED ?
NO
YES
WAS TRAIN DUMPED ?
YES
NO
INITIALIZE TRAIN'S WAIT TO BE DUMPED
TIME TRAIN STARTS TO WAIT = CLOCK
CALL PRESCHEDULED ACTIVITIES SUBROUTINE III
DETERMINE TIME OF OCCURRENCE OF TRAIN'S NEXT PRESCHEDULED ACTIVITY (T)
DOES TRAIN HAVE ANOTHER PRESCH ACTIVITY ?
NO
YES
CALL FILE SUBROUTINE
FILE EVENT TYPE 6 WITH TIME = T
A
9
WAS TRAIN WAITING TO BE DUMPED ?
NO
YES
WAS TRAIN DUMPED ?
YES
NO
INTIALIZE TRAIN'S WAIT TO BE DUMPED
TIME TRAIN STARTS TO WAIT = CLOCK
CALL BREAKDOWN SUBROUTINE III
DETERMINE TIME OF OCCURRENCE OF TRAIN'S NEXT BREAKDOWN (T)
DOES TRAIN HAVE ANOTHER BREAKDOWN ?
NO
YES
CALL FILE SUBROUTINE
FILE EVENT TYPE 8 WITH TIME = T
A

Figure IV - 4

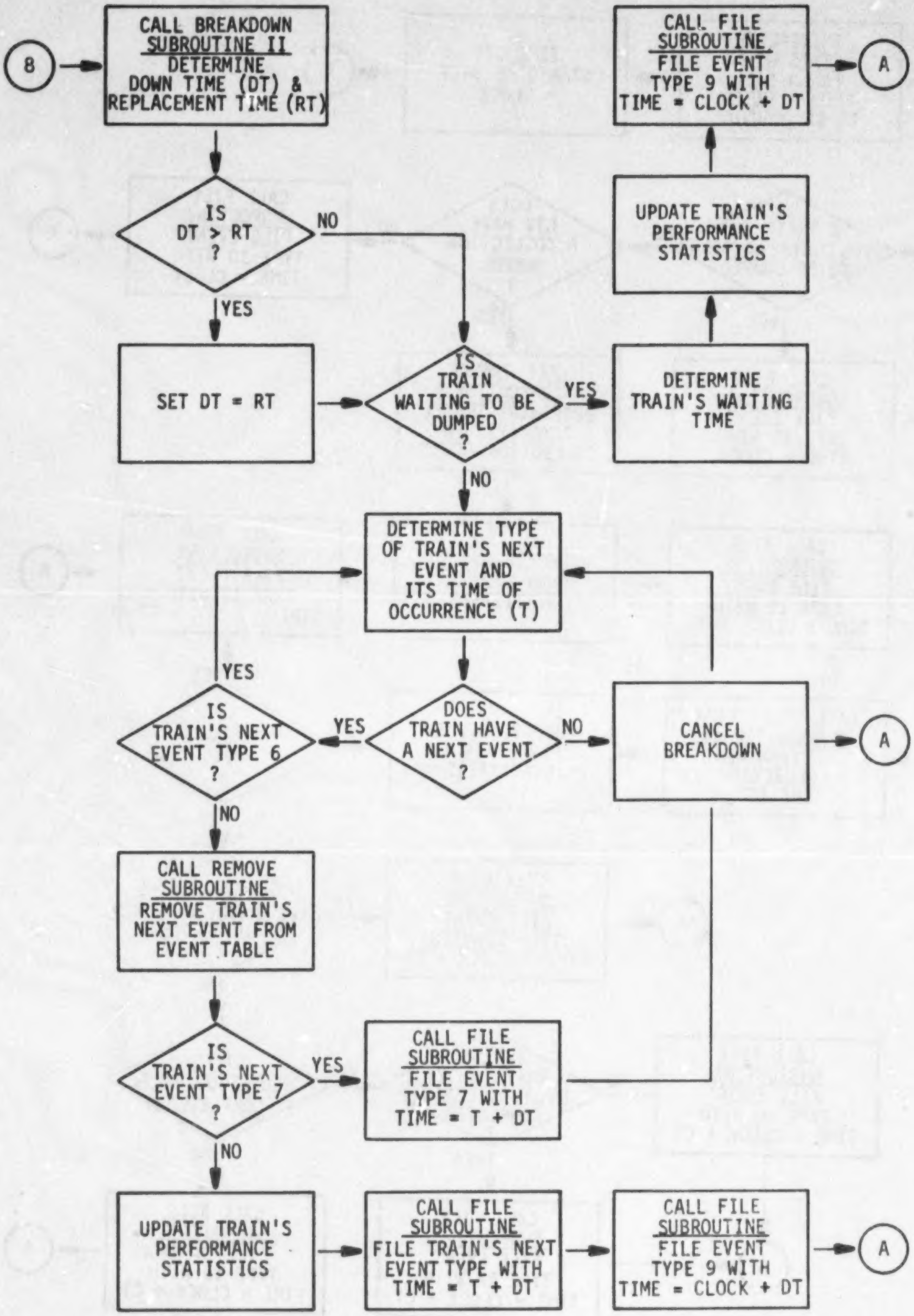
8
CALL BREAKDOWN SUBROUTINE II DETERMINE DOWN TIME (DT) & REPLACEMENT TIME (RT)
IS DT > RT ?
NO
YES
SET DT = RT
IS TRAIN WAITING TO BE DUMPED ?
YES
NO
DETERMINE TRAIN'S WAITING TIME
UPDATE TRAIN'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 9 WITH TIME = CLOCK + DT
A
DETERMINE TYPE OF TRAIN'S NEXT EVENT AND ITS TIME OF OCCURRENCE (T)
DOES TRAIN HAVE A NEXT EVENT ?
YES
NO
CANCEL BREAKDOWN
A
IS TRAIN'S NEXT EVENT TYPE 6 ?
YES
NO
CALL REMOVE SUBROUTINE REMOVE TRAIN'S NEXT EVENT FROM EVENT TABLE
IS TRAIN'S NEXT EVENT TYPE 7 ?
YES
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 7 WITH TIME = T + DT
UPDATE TRAIN'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE TRAIN'S NEXT EVENT TYPE WITH TIME = T + DT
CALL FILE SUBROUTINE FILE EVENT TYPE 9 WITH TIME = CLOCK + DT
A

Figure IV - 5

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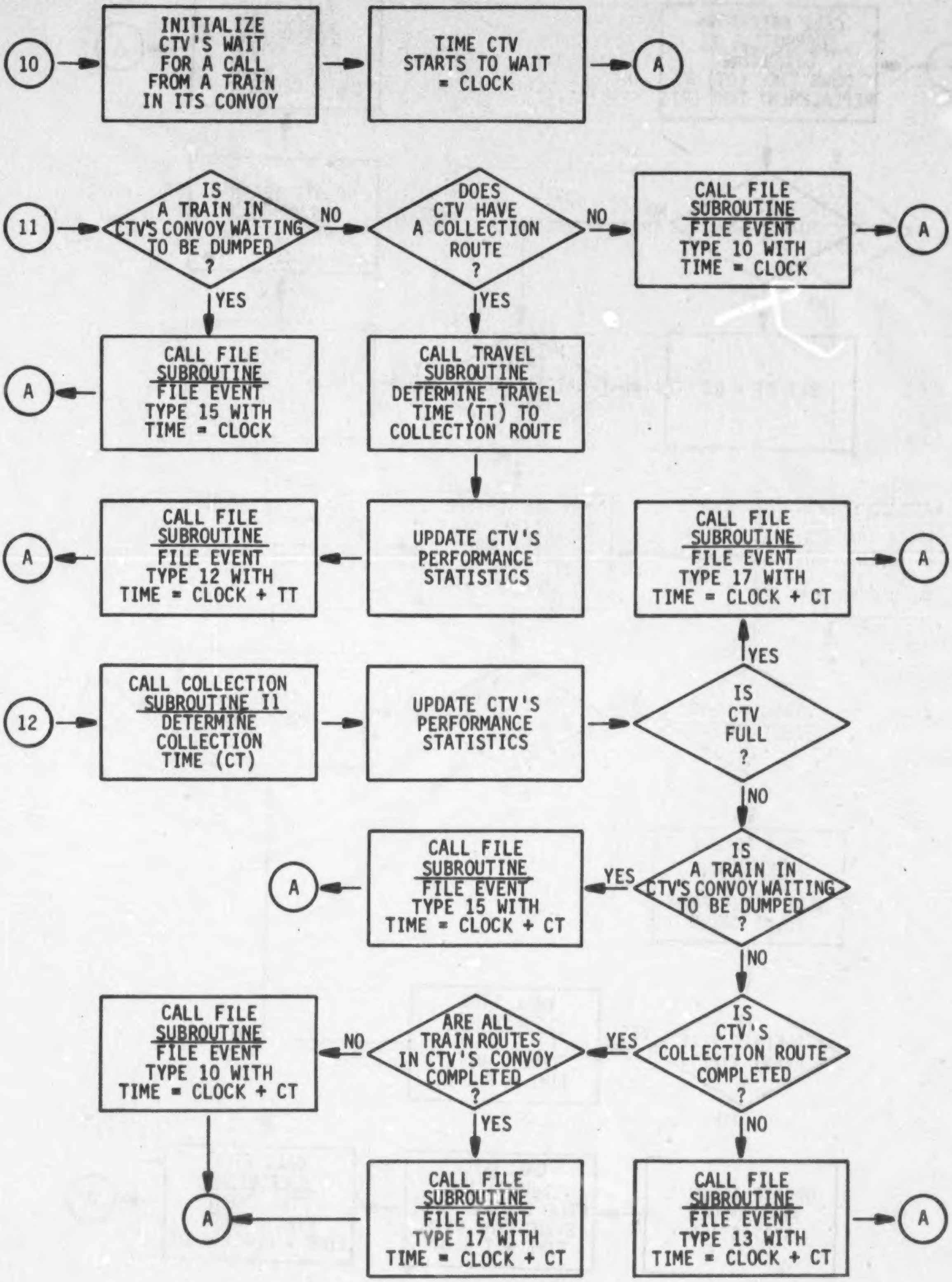
10
INITIALIZE CTV'S WAIT FOR A CALL FROM A TRAIN IN ITS CONVOY
TIME CTV STARTS TO WAIT = CLOCK
A
11
IS A TRAIN IN CTV'S CONVOY WAITING TO BE DUMPED ?
NO
DOES CTV HAVE A COLLECTION ROUTE ?
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 10 WITH TIME = CLOCK
A
YES
YES
A
CALL FILE SUBROUTINE FILE EVENT TYPE 15 WITH TIME = CLOCK
CALL TRAVEL SUBROUTINE DETERMINE TRAVEL TIME (TT) TO COLLECTION ROUTE
A
CALL FILE SUBROUTINE FILE EVENT TYPE 12 WITH TIME = CLOCK + TT
UPDATE CTV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 17 WITH TIME = CLOCK + CT
A
YES
12
CALL COLLECTION SUBROUTINE I1 DETERMINE COLLECTION TIME (CT)
UPDATE CTV'S PERFORMANCE STATISTICS
IS CTV FULL ?
NO
A
CALL FILE SUBROUTINE FILE EVENT TYPE 15 WITH TIME = CLOCK + CT
YES
IS A TRAIN IN CTV'S CONVOY WAITING TO BE DUMPED ?
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 10 WITH TIME = CLOCK + CT
NO
ARE ALL TRAIN ROUTES IN CTV'S CONVOY COMPLETED ?
YES
IS CTV'S COLLECTION ROUTE COMPLETED ?
YES
NO
A
CALL FILE SUBROUTINE FILE EVENT TYPE 17 WITH TIME = CLOCK + CT
CALL FILE SUBROUTINE FILE EVENT TYPE 13 WITH TIME = CLOCK + CT
A

Figure IV - 6

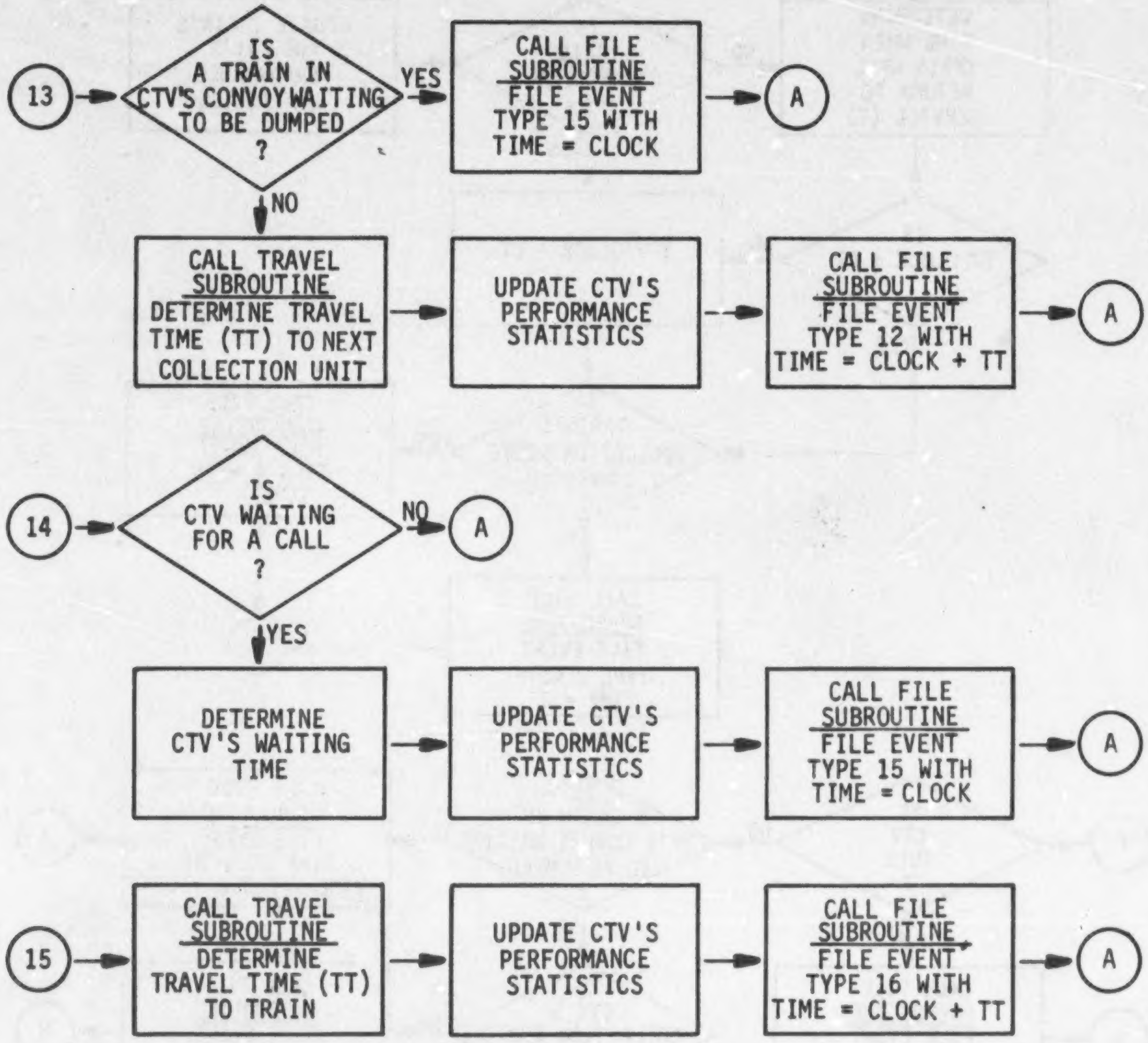
13
IS A TRAIN IN CTV'S CONVOY WAITING TO BE DUMPED ?
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 15 WITH TIME = CLOCK
A
NO
CALL TRAVEL SUBROUTINE DETERMINE TRAVEL TIME (TT) TO NEXT COLLECTION UNIT
UPDATE CTV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 12 WITH TIME = CLOCK + TT
A
14
IS CTV WAITING FOR A CALL ?
NO
A
YES
DETERMINE CTV'S WAITING TIME
UPDATE CTV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 15 WITH TIME = CLOCK
A
15
CALL TRAVEL SUBROUTINE DETERMINE TRAVEL TIME (TT) TO TRAIN
UPDATE CTV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 16 WITH TIME = CLOCK + TT
A

Figure IV - 7

(141)

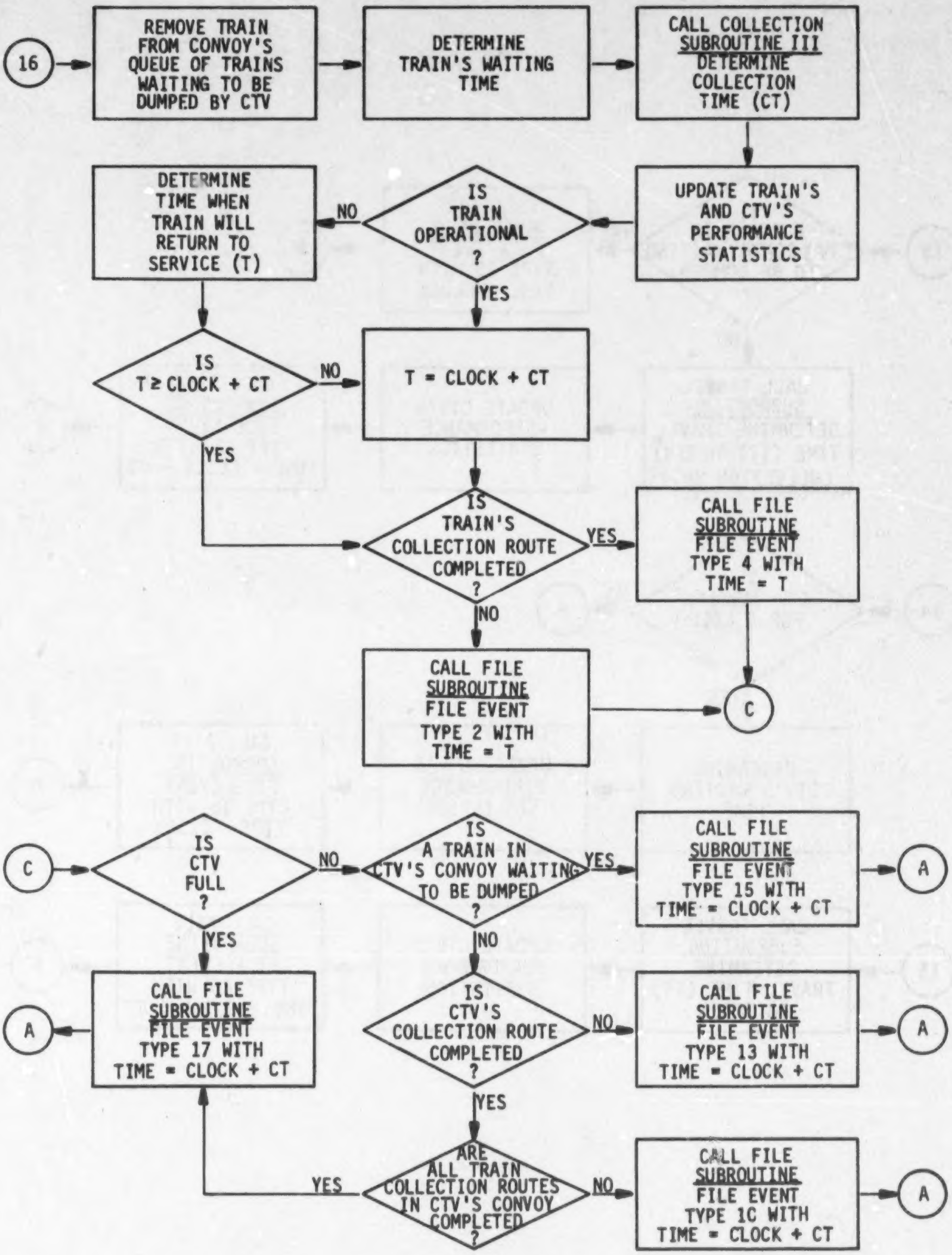
16
REMOVE TRAIN FROM CONVOY'S QUEUE OF TRAINS WAITING TO BE DUMPED BY CTV
DETERMINE TRAIN'S WAITING TIME
CALL COLLECTION SUBROUTINE III DETERMINE COLLECTION TIME (CT)
UPDATE TRAIN'S AND CTV'S PERFORMANCE STATISTICS
IS TRAIN OPERATIONAL ?
NO
YES
DETERMINE TIME WHEN TRAIN WILL RETURN TO SERVICE (T)
IS T ≥ CLOCK + CT
NO
YES
T = CLOCK + CT
IS TRAIN'S COLLECTION ROUTE COMPLETED ?
YES
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 4 WITH TIME = T
CALL FILE SUBROUTINE FILE EVENT TYPE 2 WITH TIME = T
C
C
IS CTV FULL ?
NO
YES
IS A TRAIN IN CTV'S CONVOY WAITING TO BE DUMPED ?
YES
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 15 WITH TIME = CLOCK + CT
A
A
CALL FILE SUBROUTINE FILE EVENT TYPE 17 WITH TIME = CLOCK + CT
IS CTV'S COLLECTION ROUTE COMPLETED ?
NO
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 13 WITH TIME = CLOCK + CT
A
YES
ARE ALL TRAIN COLLECTION ROUTES IN CTV'S CONVOY COMPLETED ?
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 1C WITH TIME = CLOCK + CT
A

Figure IV - 8

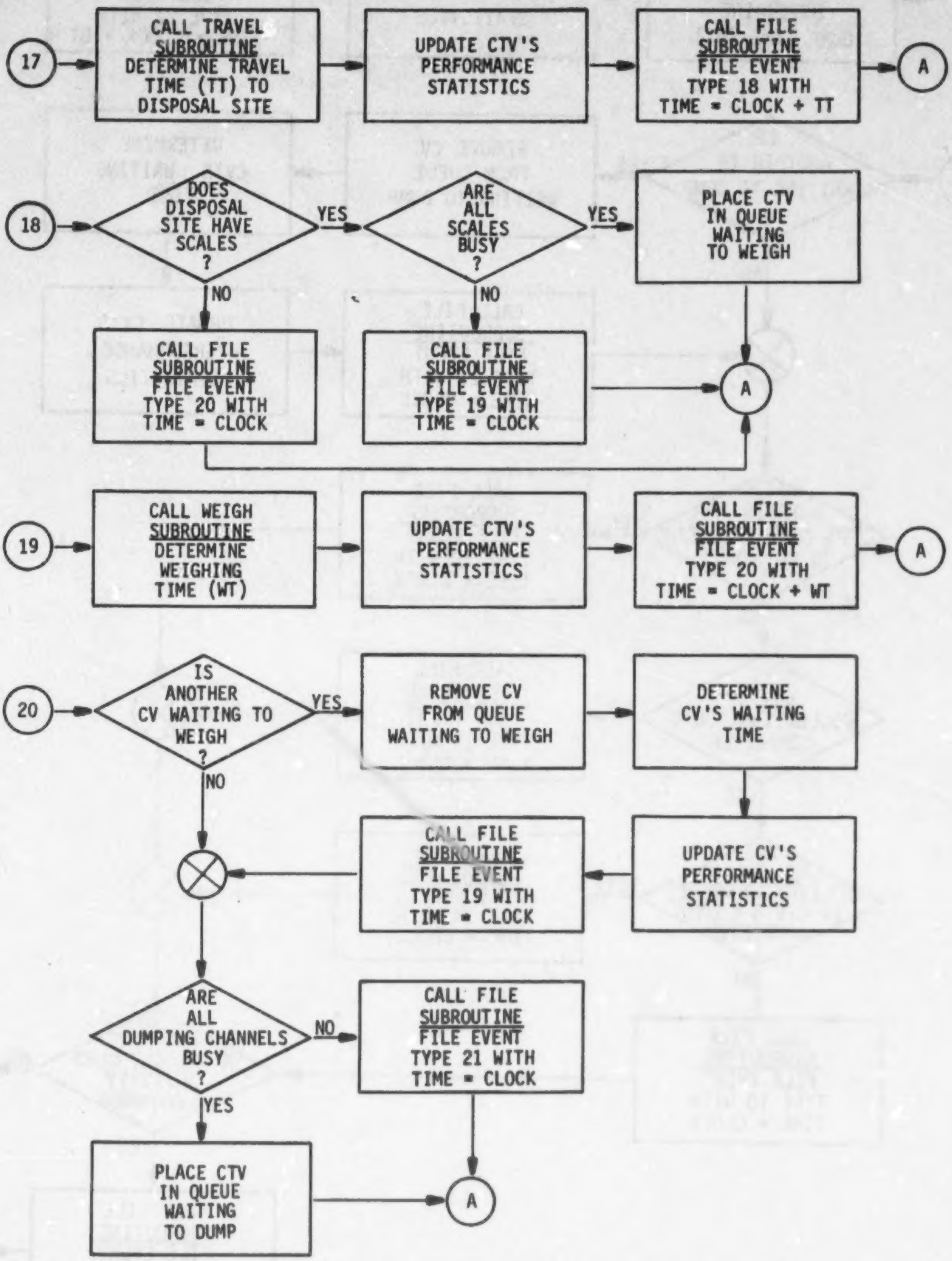
17
CALL TRAVEL SUBROUTINE DETERMINE TRAVEL TIME (TT) TO DISPOSAL SITE
UPDATE CTV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 18 WITH TIME = CLOCK + TT
A
18
DOES DISPOSAL SITE HAVE SCALES ?
YES
ARE ALL SCALES BUSY ?
YES
PLACE CTV IN QUEUE WAITING TO WEIGH
NO
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 20 WITH TIME = CLOCK
CALL FILE SUBROUTINE FILE EVENT TYPE 19 WITH TIME = CLOCK
A
19
CALL WEIGH SUBROUTINE DETERMINE WEIGHING TIME (WT)
UPDATE CTV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 20 WITH TIME = CLOCK + WT
A
20
IS ANOTHER CV WAITING TO WEIGH ?
YES
REMOVE CV FROM QUEUE WAITING TO WEIGH
DETERMINE CV'S WAITING TIME
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 19 WITH TIME = CLOCK
UPDATE CV'S PERFORMANCE STATISTICS
ARE ALL DUMPING CHANNELS BUSY ?
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 21 WITH TIME = CLOCK
YES
PLACE CTV IN QUEUE WAITING TO DUMP
A

Figure IV - 9

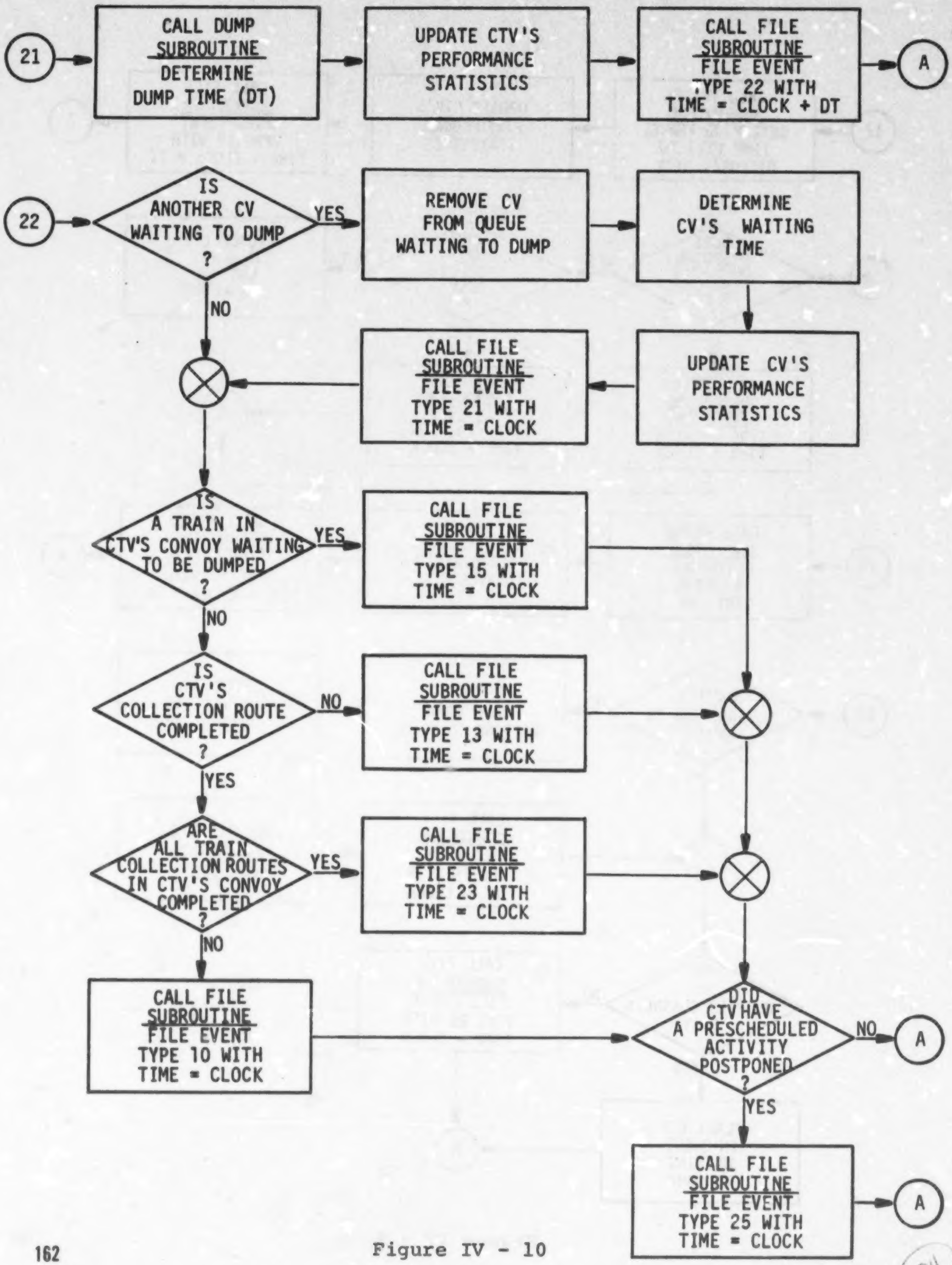
21
CALL DUMP SUBROUTINE DETERMINE DUMP TIME (DT)
UPDATE CTV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 22 WITH TIME = CLOCK + DT
A
22
IS ANOTHER CV WAITING TO DUMP ?
YES
NO
REMOVE CV FROM QUEUE WAITING TO DUMP
DETERMINE CV'S WAITING TIME
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 21 WITH TIME = CLOCK
IS A TRAIN IN CTV'S CONVOY WAITING TO BE DUMPED ?
YES
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 15 WITH TIME = CLOCK
IS CTV'S COLLECTION ROUTE COMPLETED ?
NO
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 13 WITH TIME = CLOCK
ARE ALL TRAIN COLLECTION ROUTES IN CTV'S CONVOY COMPLETED ?
YES
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 23 WITH TIME = CLOCK
CALL FILE SUBROUTINE FILE EVENT TYPE 10 WITH TIME = CLOCK
DID CTV HAVE A PRESCHEDULED ACTIVITY POSTPONED ?
NO
A
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 25 WITH TIME = CLOCK
A

Figure IV - 10

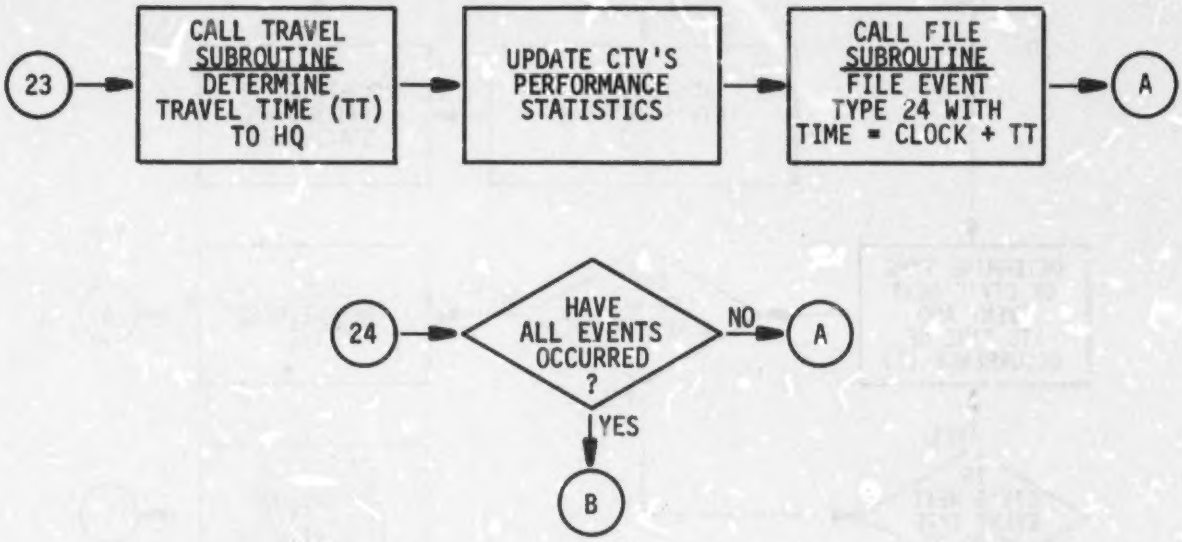
23
CALL TRAVEL
SUBROUTINE
DETERMINE
TRAVEL TIME (TT)
TO HQ
UPDATE CTV'S
PERFORMANCE
STATISTICS
CALL FILE
SUBROUTINE
FILE EVENT
TYPE 24 WITH
TIME = CLOCK + TT
A
24
HAVE
ALL EVENTS
OCCURRED
?
NO
A
YES
B

Figure IV - 11

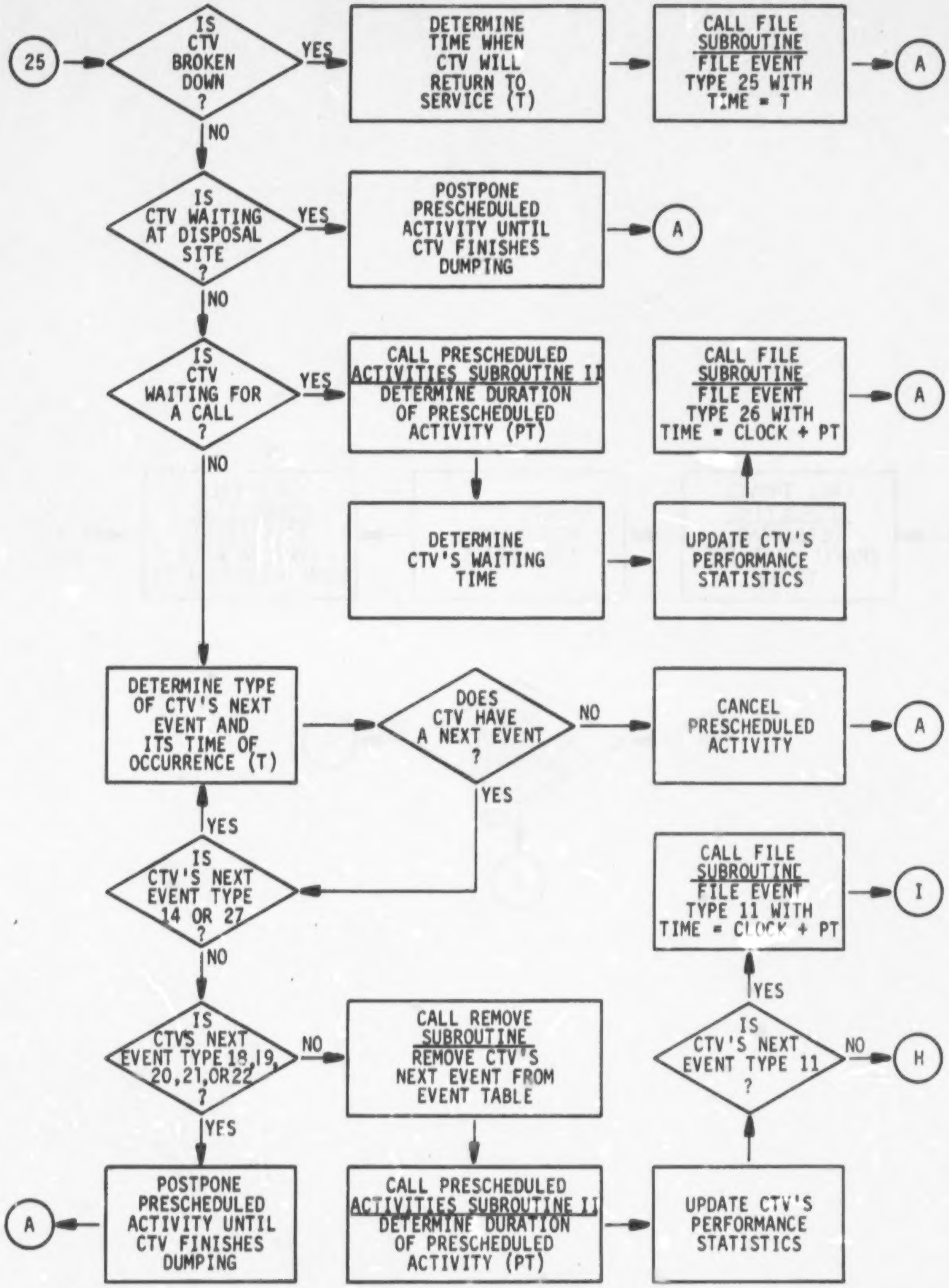
25
IS CTV BROKEN DOWN ?
YES
DETERMINE TIME WHEN CTV WILL RETURN TO SERVICE (T)
CALL FILE SUBROUTINE
FILE EVENT TYPE 25 WITH TIME = T
A
NO
IS CTV WAITING AT DISPOSAL SITE ?
YES
POSTPONE PRESCHEDULED ACTIVITY UNTIL CTV FINISHES DUMPING
A
NO
IS CTV WAITING FOR A CALL ?
YES
CALL PRESCHEDULED ACTIVITIES SUBROUTINE II
DETERMINE DURATION OF PRESCHEDULED ACTIVITY (PT)
CALL FILE SUBROUTINE
FILE EVENT TYPE 26 WITH TIME = CLOCK + PT
A
DETERMINE CTV'S WAITING TIME
UPDATE CTV'S PERFORMANCE STATISTICS
NO
DETERMINE TYPE OF CTV'S NEXT EVENT AND ITS TIME OF OCCURRENCE (T)
DOES CTV HAVE A NEXT EVENT ?
NO
CANCEL PRESCHEDULED ACTIVITY
A
YES
YES
IS CTV'S NEXT EVENT TYPE 14 OR 27 ?
CALL FILE SUBROUTINE
FILE EVENT TYPE 11 WITH TIME = CLOCK + PT
I
NO
YES
IS CTVS NEXT EVENT TYPE 18,19, 20,21,OR22 ?
NO
CALL REMOVE SUBROUTINE
REMOVE CTV'S NEXT EVENT FROM EVENT TABLE
IS CTV'S NEXT EVENT TYPE 11 ?
NO
H
YES
A
POSTPONE PRESCHEDULED ACTIVITY UNTIL CTV FINISHES DUMPING
CALL PRESCHEDULED ACTIVITIES SUBROUTINE II
DETERMINE DURATION OF PRESCHEDULED ACTIVITY (PT)
UPDATE CTV'S PERFORMANCE STATISTICS

Figure IV - 12

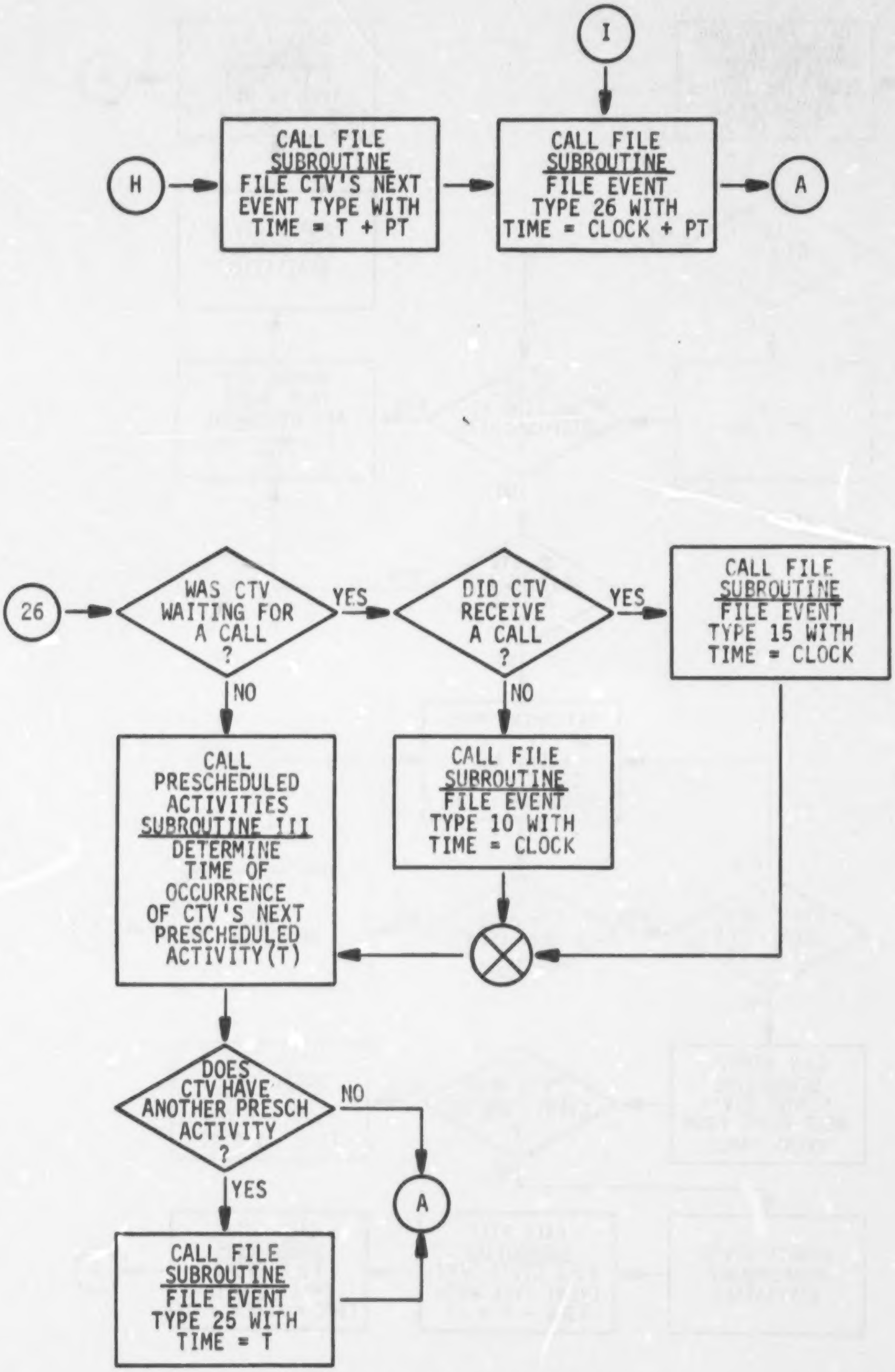
I
H
CALL FILE SUBROUTINE
FILE CTV'S NEXT EVENT TYPE WITH TIME = T + PT
CALL FILE SUBROUTINE
FILE EVENT TYPE 26 WITH TIME = CLOCK + PT
A
26
WAS CTV WAITING FOR A CALL ?
YES
DID CTV RECEIVE A CALL ?
YES
CALL FILE SUBROUTINE
FILE EVENT TYPE 15 WITH TIME = CLOCK
NO
NO
CALL PRESCHEDULED ACTIVITIES SUBROUTINE III
DETERMINE TIME OF OCCURRENCE OF CTV'S NEXT PRESCHEDULED ACTIVITY (T)
CALL FILE SUBROUTINE
FILE EVENT TYPE 10 WITH TIME = CLOCK
DOES CTV HAVE ANOTHER PRESCH ACTIVITY ?
NO
YES
A
CALL FILE SUBROUTINE
FILE EVENT TYPE 25 WITH TIME = T

Figure IV - 13

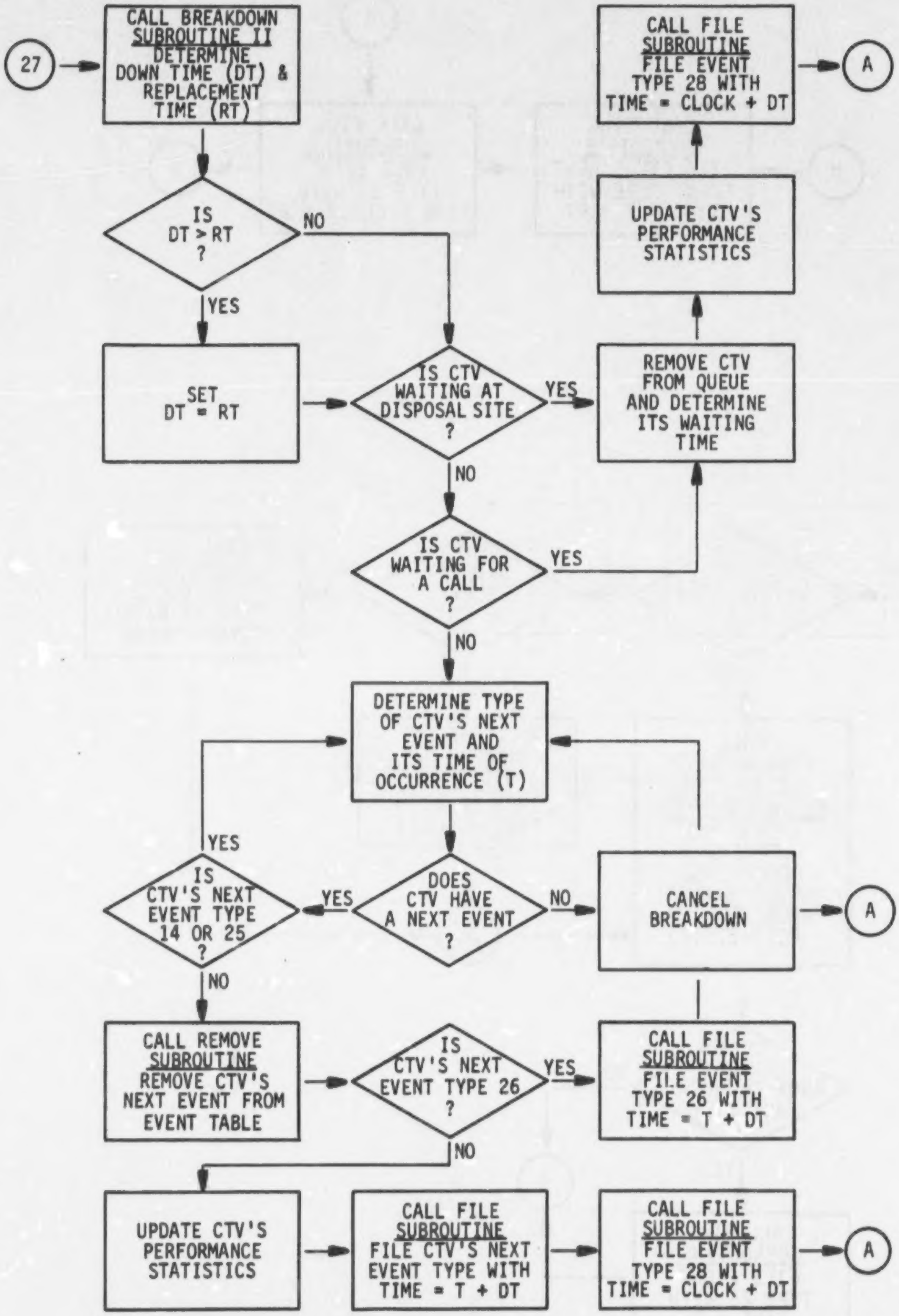
27
CALL BREAKDOWN SUBROUTINE II DETERMINE DOWN TIME (DT) & REPLACEMENT TIME (RT)
IS DT > RT ?
NO
YES
SET DT = RT
IS CTV WAITING AT DISPOSAL SITE ?
YES
NO
IS CTV WAITING FOR A CALL ?
YES
NO
REMOVE CTV FROM QUEUE AND DETERMINE ITS WAITING TIME
UPDATE CTV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 28 WITH TIME = CLOCK + DT
A
DETERMINE TYPE OF CTV'S NEXT EVENT AND ITS TIME OF OCCURRENCE (T)
YES
IS CTV'S NEXT EVENT TYPE 14 OR 25 ?
YES
DOES CTV HAVE A NEXT EVENT ?
NO
CANCEL BREAKDOWN
A
NO
CALL REMOVE SUBROUTINE REMOVE CTV'S NEXT EVENT FROM EVENT TABLE
IS CTV'S NEXT EVENT TYPE 26 ?
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 26 WITH TIME = T + DT
NO
UPDATE CTV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE CTV'S NEXT EVENT TYPE WITH TIME = T + DT
CALL FILE SUBROUTINE FILE EVENT TYPE 28 WITH TIME = CLOCK + DT
A

Figure IV - 14

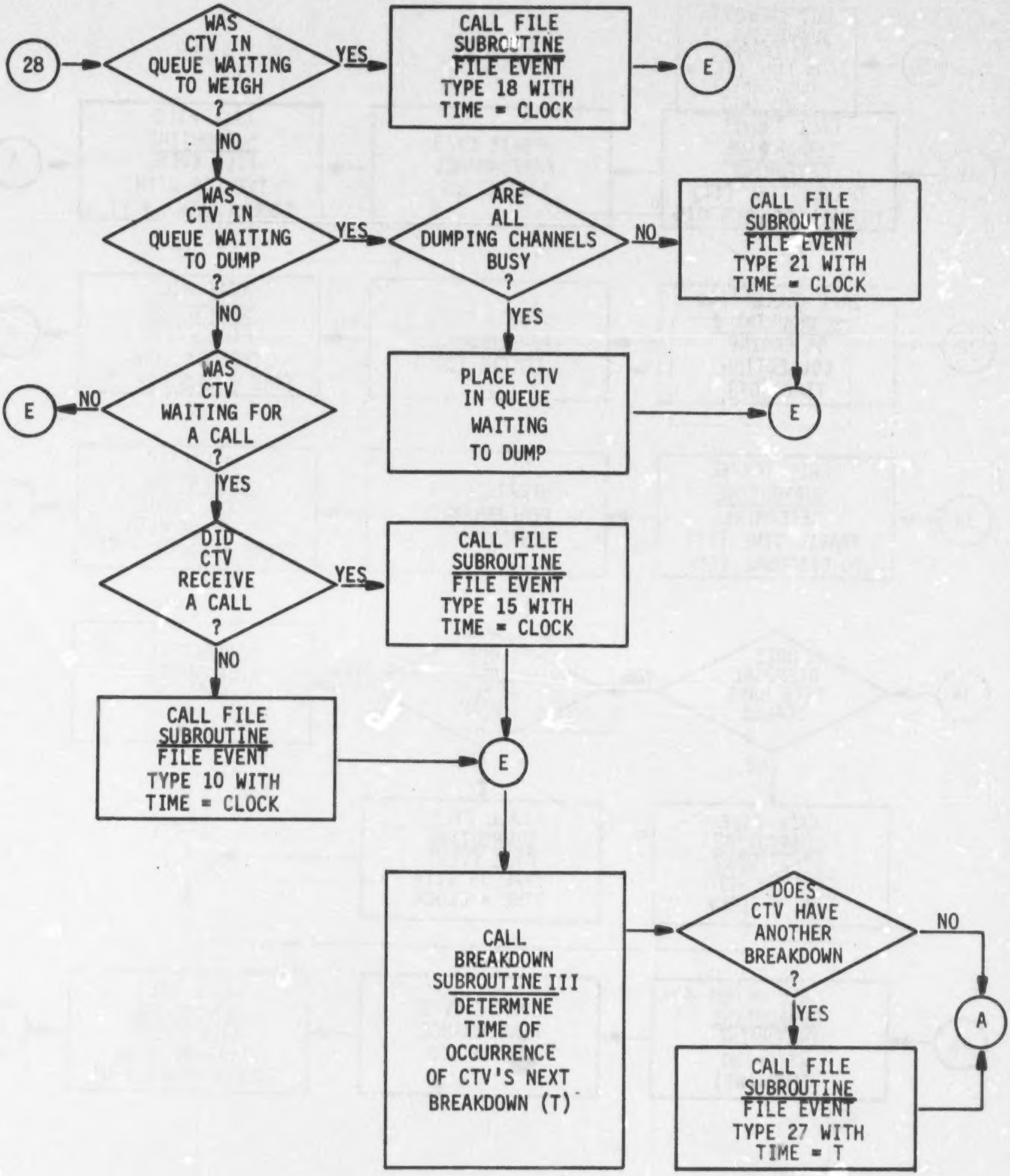
28
WAS CTV IN QUEUE WAITING TO WEIGH ?
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 18 WITH TIME = CLOCK
E
NO
WAS CTV IN QUEUE WAITING TO DUMP ?
YES
ARE ALL DUMPING CHANNELS BUSY ?
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 21 WITH TIME = CLOCK
NO
YES
PLACE CTV IN QUEUE WAITING TO DUMP
E
E
NO
WAS CTV WAITING FOR A CALL ?
YES
DID CTV RECEIVE A CALL ?
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 15 WITH TIME = CLOCK
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 10 WITH TIME = CLOCK
E
CALL BREAKDOWN SUBROUTINE III DETERMINE TIME OF OCCURRENCE OF CTV'S NEXT BREAKDOWN (T)
DOES CTV HAVE ANOTHER BREAKDOWN ?
NO
YES
A
CALL FILE SUBROUTINE FILE EVENT TYPE 27 WITH TIME = T

Figure IV - 15

189

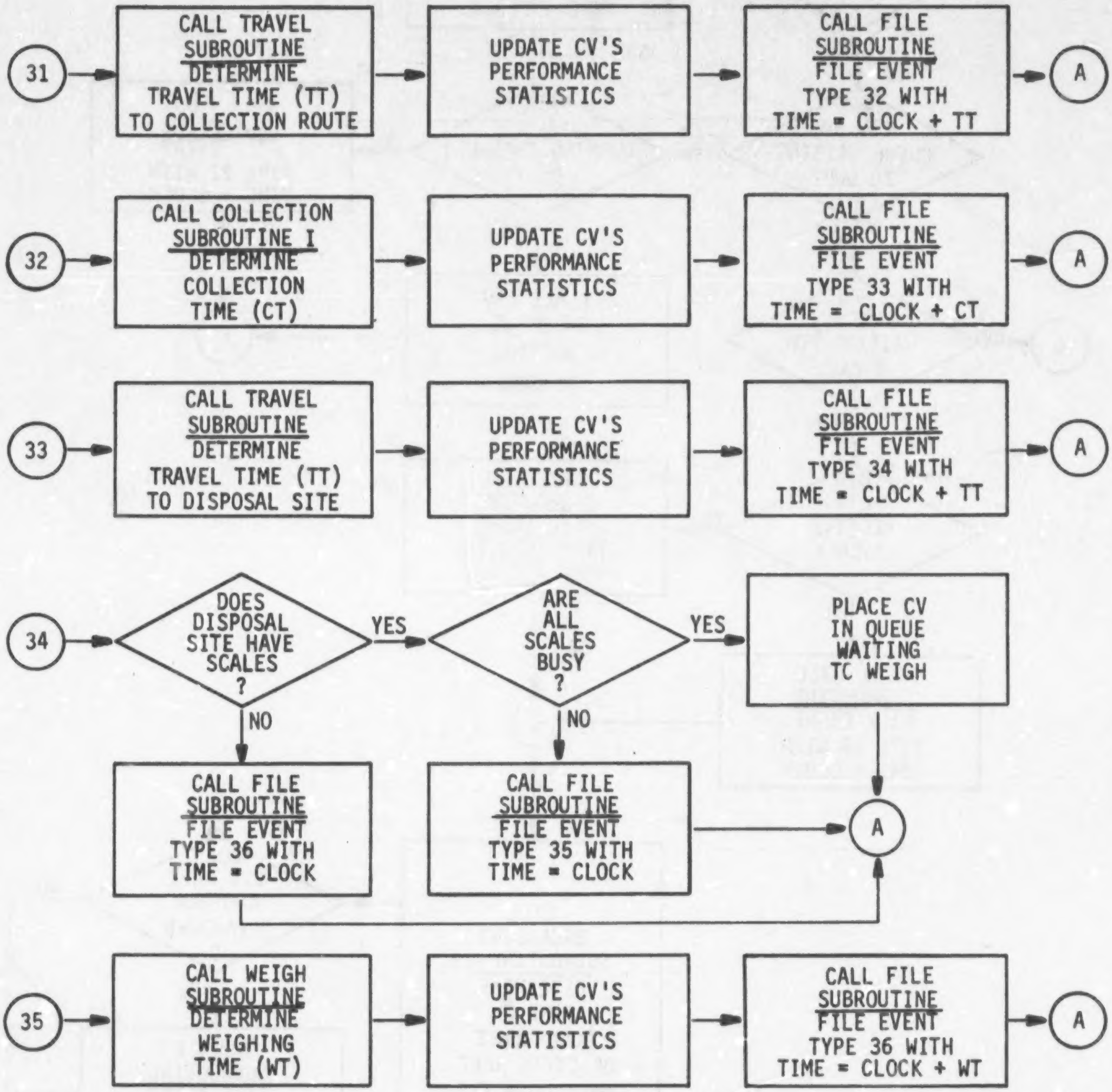
31
CALL TRAVEL SUBROUTINE DETERMINE TRAVEL TIME (TT) TO COLLECTION ROUTE
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 32 WITH TIME = CLOCK + TT
A
32
CALL COLLECTION SUBROUTINE I DETERMINE COLLECTION TIME (CT)
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 33 WITH TIME = CLOCK + CT
A
33
CALL TRAVEL SUBROUTINE DETERMINE TRAVEL TIME (TT) TO DISPOSAL SITE
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 34 WITH TIME = CLOCK + TT
A
34
DOES DISPOSAL SITE HAVE SCALES ?
YES
ARE ALL SCALES BUSY ?
YES
PLACE CV IN QUEUE WAITING TC WEIGH
NO
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 36 WITH TIME = CLOCK
CALL FILE SUBROUTINE FILE EVENT TYPE 35 WITH TIME = CLOCK
A
35
CALL WEIGH SUBROUTINE DETERMINE WEIGHING TIME (WT)
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 36 WITH TIME = CLOCK + WT
A

Figure IV - 16

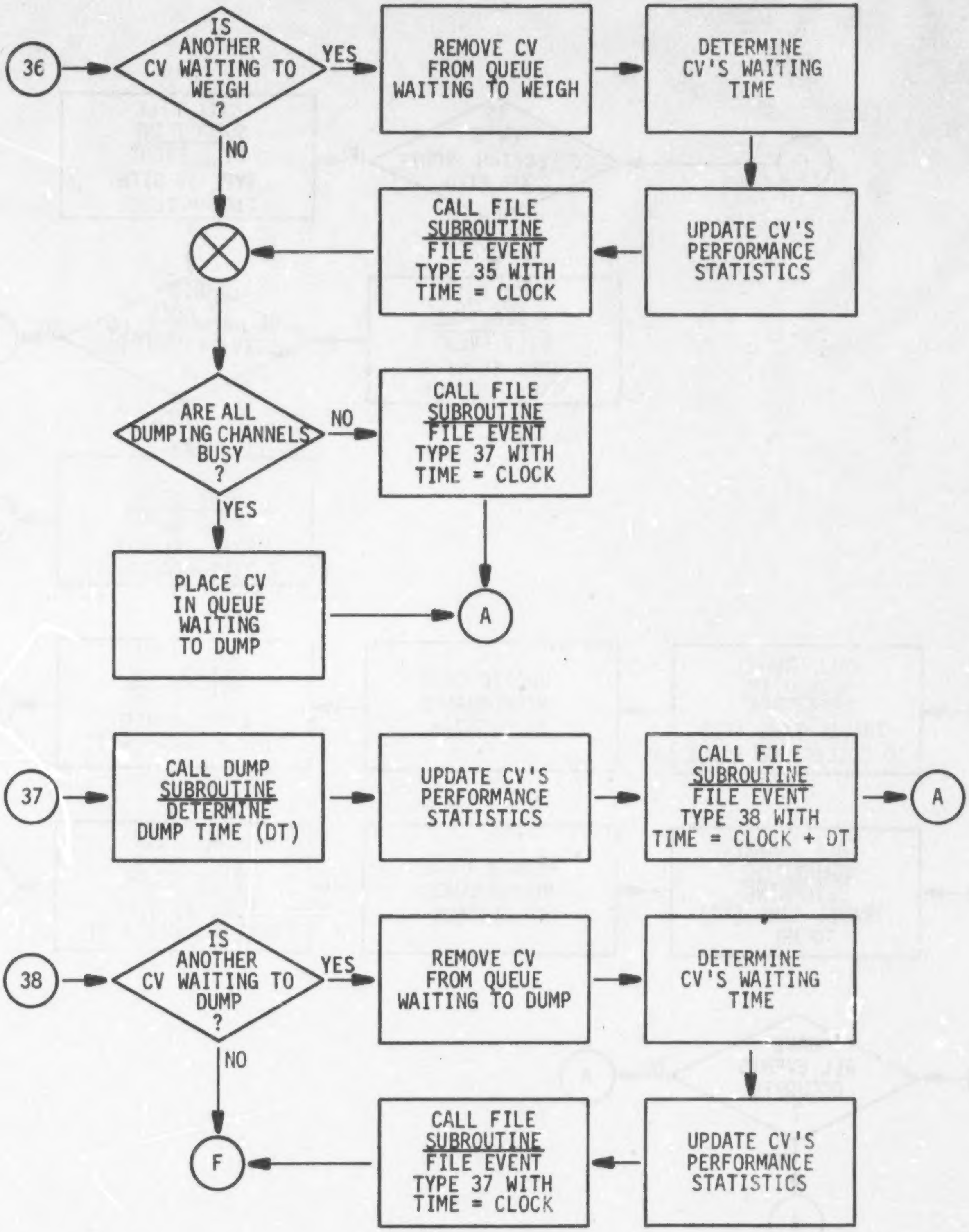
36
IS ANOTHER CV WAITING TO WEIGH ?
YES
NO
REMOVE CV FROM QUEUE WAITING TO WEIGH
DETERMINE CV'S WAITING TIME
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 35 WITH TIME = CLOCK
ARE ALL DUMPING CHANNELS BUSY ?
NO
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 37 WITH TIME = CLOCK
PLACE CV IN QUEUE WAITING TO DUMP
A
37
CALL DUMP SUBROUTINE DETERMINE DUMP TIME (DT)
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 38 WITH TIME = CLOCK + DT
A
38
IS ANOTHER CV WAITING TO DUMP ?
YES
NO
REMOVE CV FROM QUEUE WAITING TO DUMP
DETERMINE CV'S WAITING TIME
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 37 WITH TIME = CLOCK
F

Figure IV - 17

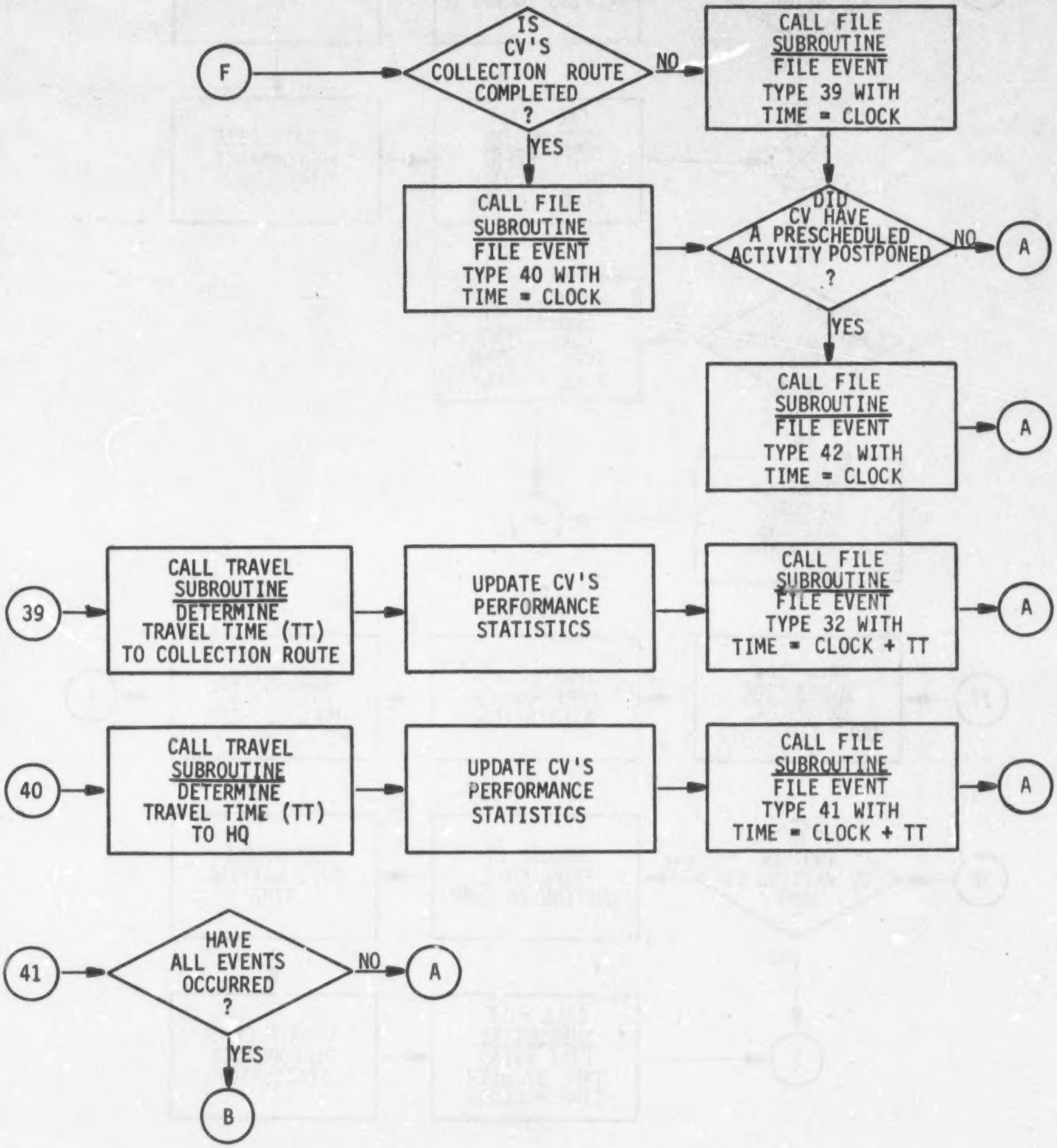
F
IS CV'S COLLECTION ROUTE COMPLETED ?
NO
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 39 WITH TIME = CLOCK
CALL FILE SUBROUTINE FILE EVENT TYPE 40 WITH TIME = CLOCK
DID CV HAVE A PRESCHEDULED ACTIVITY POSTPONED ?
NO
A
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 42 WITH TIME = CLOCK
A
39
CALL TRAVEL SUBROUTINE DETERMINE TRAVEL TIME (TT) TO COLLECTION ROUTE
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 32 WITH TIME = CLOCK + TT
A
40
CALL TRAVEL SUBROUTINE DETERMINE TRAVEL TIME (TT) TO HQ
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 41 WITH TIME = CLOCK + TT
A
41
HAVE ALL EVENTS OCCURRED ?
NO
A
YES
B

Figure IV - 18

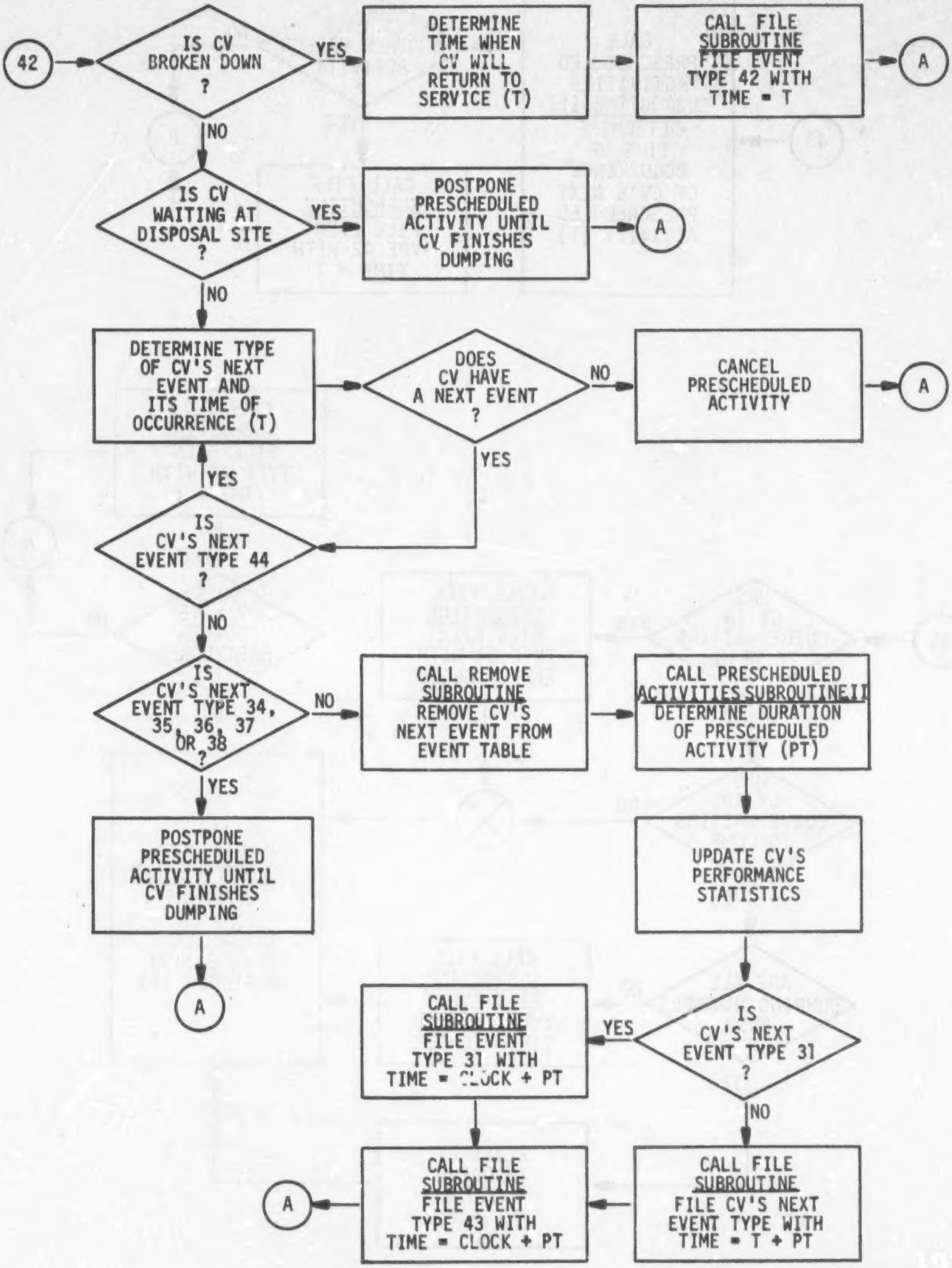
42
IS CV BROKEN DOWN ?
YES
DETERMINE TIME WHEN CV WILL RETURN TO SERVICE (T)
CALL FILE SUBROUTINE FILE EVENT TYPE 42 WITH TIME = T
A
NO
IS CV WAITING AT DISPOSAL SITE ?
YES
POSTPONE PRESCHEDULED ACTIVITY UNTIL CV FINISHES DUMPING
A
NO
DETERMINE TYPE OF CV'S NEXT EVENT AND ITS TIME OF OCCURRENCE (T)
DOES CV HAVE A NEXT EVENT ?
NO
CANCEL PRESCHEDULED ACTIVITY
A
YES
YES
IS CV'S NEXT EVENT TYPE 44 ?
NO
IS CV'S NEXT EVENT TYPE 34, 35, 36, 37 OR 38 ?
NO
CALL REMOVE SUBROUTINE REMOVE CV'S NEXT EVENT FROM EVENT TABLE
CALL PRESCHEDULED ACTIVITIES SUBROUTINE II DETERMINE DURATION OF PRESCHEDULED ACTIVITY (PT)
YES
POSTPONE PRESCHEDULED ACTIVITY UNTIL CV FINISHES DUMPING
A
UPDATE CV'S PERFORMANCE STATISTICS
IS CV'S NEXT EVENT TYPE 31 ?
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 31 WITH TIME = CLOCK + PT
NO
CALL FILE SUBROUTINE FILE CV'S NEXT EVENT TYPE WITH TIME = T + PT
CALL FILE SUBROUTINE FILE EVENT TYPE 43 WITH TIME = CLOCK + PT
A

Figure IV - 19

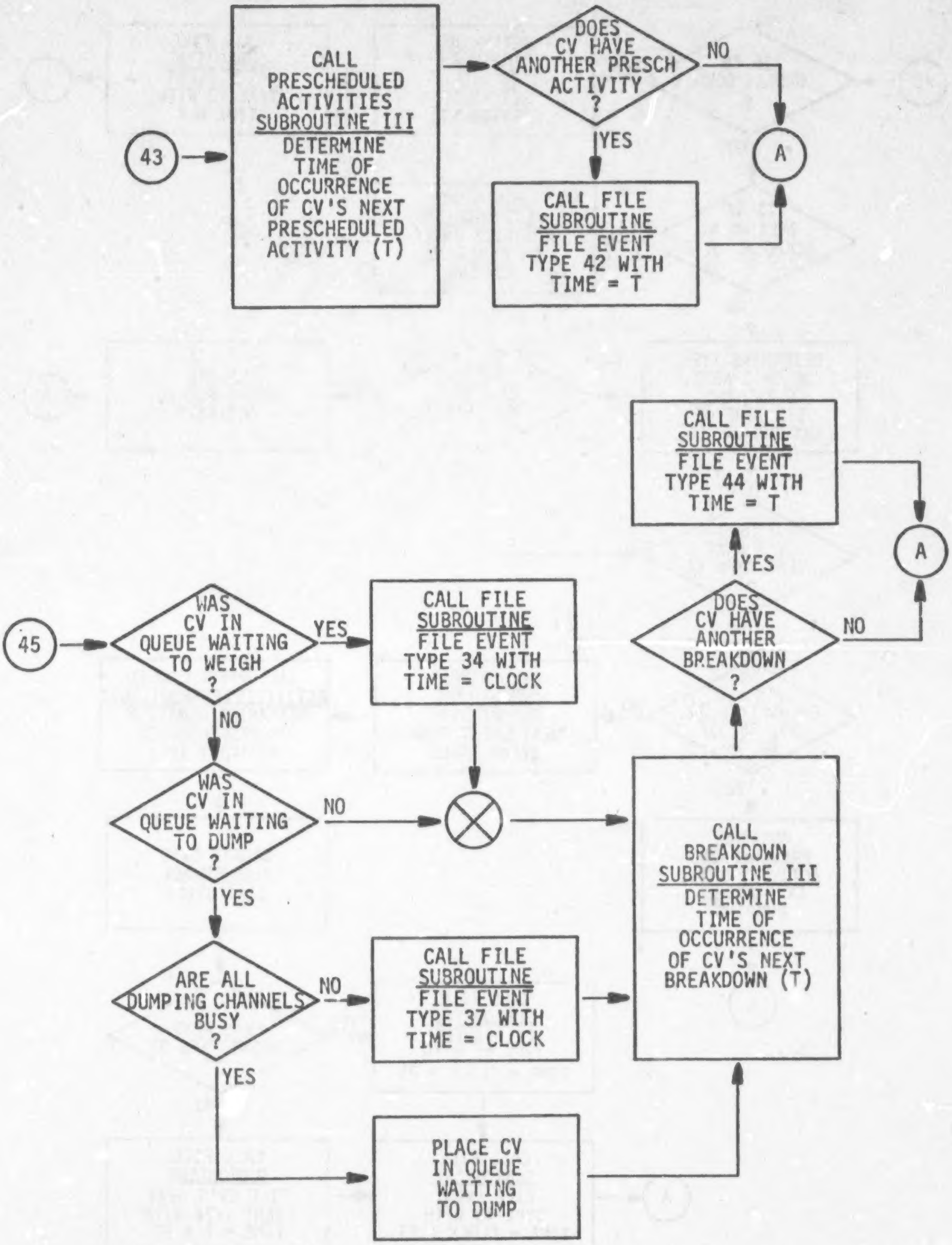
43
CALL PRESCHEDULED ACTIVITIES SUBROUTINE III
DETERMINE TIME OF OCCURRENCE OF CV'S NEXT PRESCHEDULED ACTIVITY (T)
DOES CV HAVE ANOTHER PRESCH ACTIVITY ?
NO
YES
A
CALL FILE SUBROUTINE
FILE EVENT TYPE 42 WITH TIME = T
45
WAS CV IN QUEUE WAITING TO WEIGH ?
YES
NO
CALL FILE SUBROUTINE
FILE EVENT TYPE 34 WITH TIME = CLOCK
WAS CV IN QUEUE WAITING TO DUMP ?
NO
YES
ARE ALL DUMPING CHANNELS BUSY ?
NO
YES
CALL FILE SUBROUTINE
FILE EVENT TYPE 37 WITH TIME = CLOCK
PLACE CV IN QUEUE WAITING TO DUMP
CALL BREAKDOWN SUBROUTINE III
DETERMINE TIME OF OCCURRENCE OF CV'S NEXT BREAKDOWN (T)
DOES CV HAVE ANOTHER BREAKDOWN ?
YES
NO
CALL FILE SUBROUTINE
FILE EVENT TYPE 44 WITH TIME = T
A

Figure IV - 20

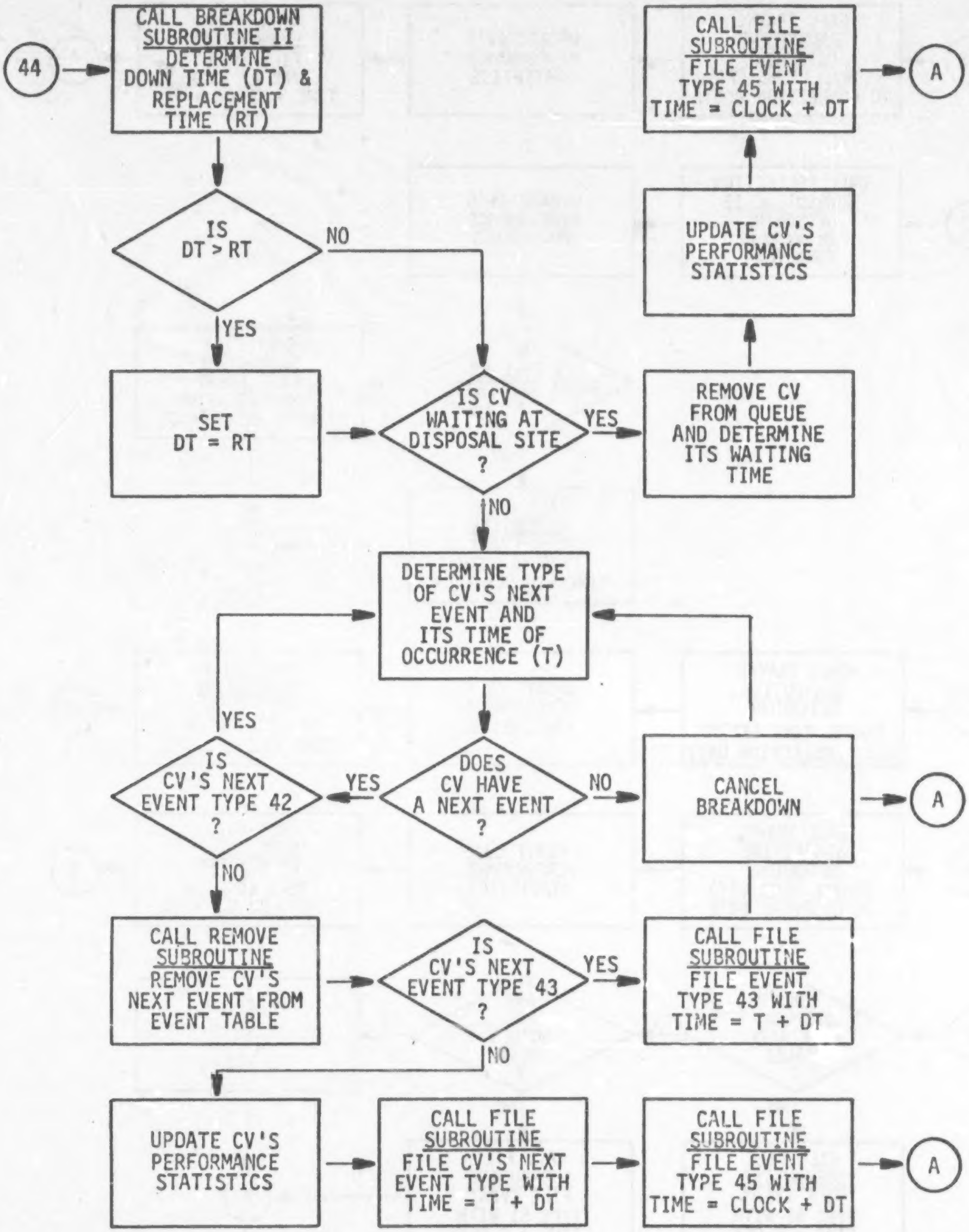
44
CALL BREAKDOWN SUBROUTINE II DETERMINE DOWN TIME (DT) & REPLACEMENT TIME (RT)
IS DT > RT
NO
YES
SET DT = RT
IS CV WAITING AT DISPOSAL SITE ?
YES
NO
REMOVE CV FROM QUEUE AND DETERMINE ITS WAITING TIME
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 45 WITH TIME = CLOCK + DT
A
DETERMINE TYPE OF CV'S NEXT EVENT AND ITS TIME OF OCCURRENCE (T)
DOES CV HAVE A NEXT EVENT ?
YES
NO
IS CV'S NEXT EVENT TYPE 42 ?
YES
NO
CANCEL BREAKDOWN
A
CALL REMOVE SUBROUTINE REMOVE CV'S NEXT EVENT FROM EVENT TABLE
IS CV'S NEXT EVENT TYPE 43 ?
YES
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 43 WITH TIME = T + DT
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE CV'S NEXT EVENT TYPE WITH TIME = T + DT
CALL FILE SUBROUTINE FILE EVENT TYPE 45 WITH TIME = CLOCK + DT
A

Figure IV - 21

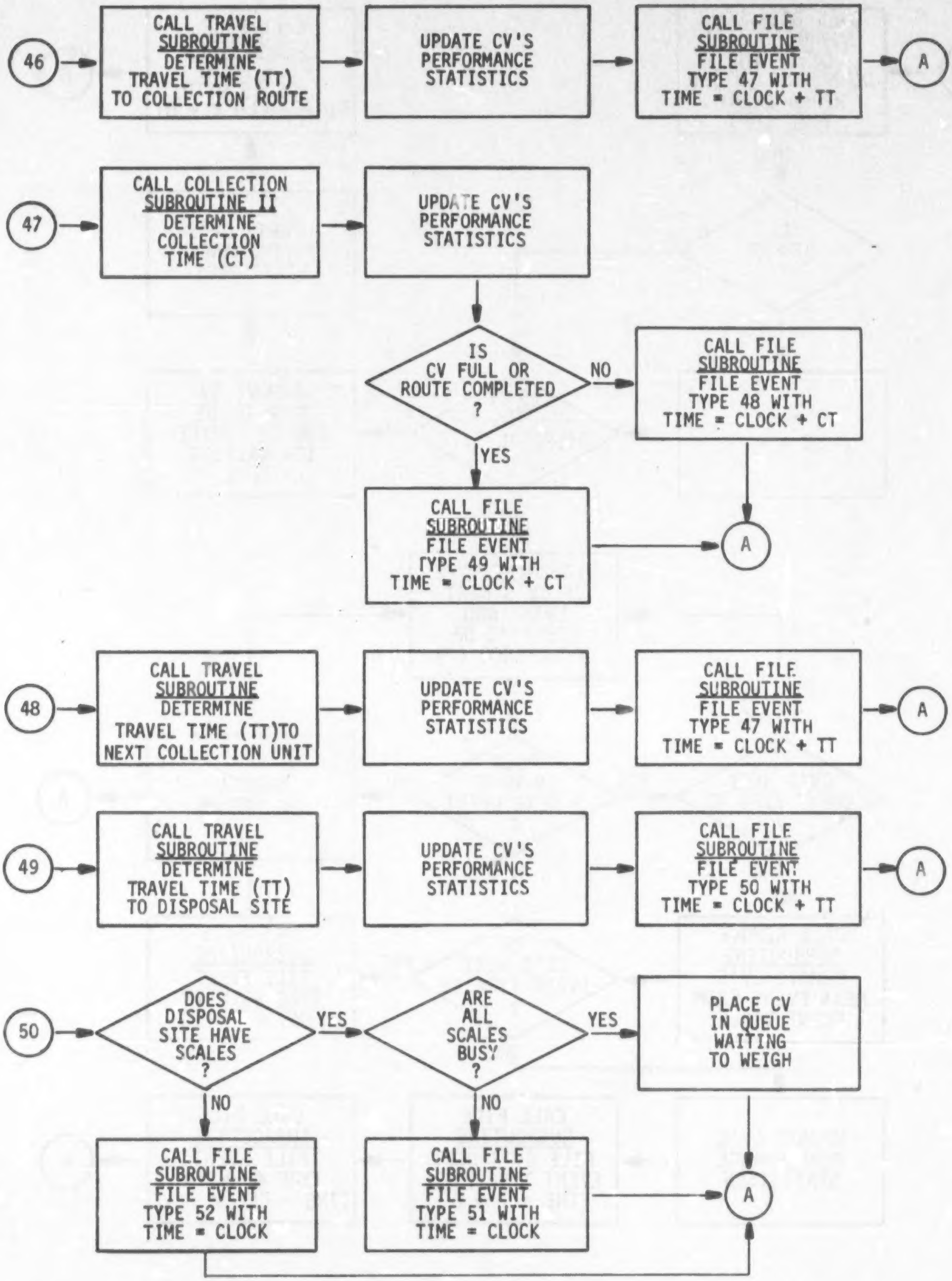
46
CALL TRAVEL SUBROUTINE DETERMINE TRAVEL TIME (TT) TO COLLECTION ROUTE
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 47 WITH TIME = CLOCK + TT
A
47
CALL COLLECTION SUBROUTINE II DETERMINE COLLECTION TIME (CT)
UPDATE CV'S PERFORMANCE STATISTICS
IS CV FULL OR ROUTE COMPLETED ?
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 48 WITH TIME = CLOCK + CT
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 49 WITH TIME = CLOCK + CT
A
48
CALL TRAVEL SUBROUTINE DETERMINE TRAVEL TIME (TT)TO NEXT COLLECTION UNIT
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 47 WITH TIME = CLOCK + TT
A
49
CALL TRAVEL SUBROUTINE DETERMINE TRAVEL TIME (TT) TO DISPOSAL SITE
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 50 WITH TIME = CLOCK + TT
A
50
DOES DISPOSAL SITE HAVE SCALES ?
YES
ARE ALL SCALES BUSY ?
YES
PLACE CV IN QUEUE WAITING TO WEIGH
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 52 WITH TIME = CLOCK
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 51 WITH TIME = CLOCK
A

Figure IV - 22

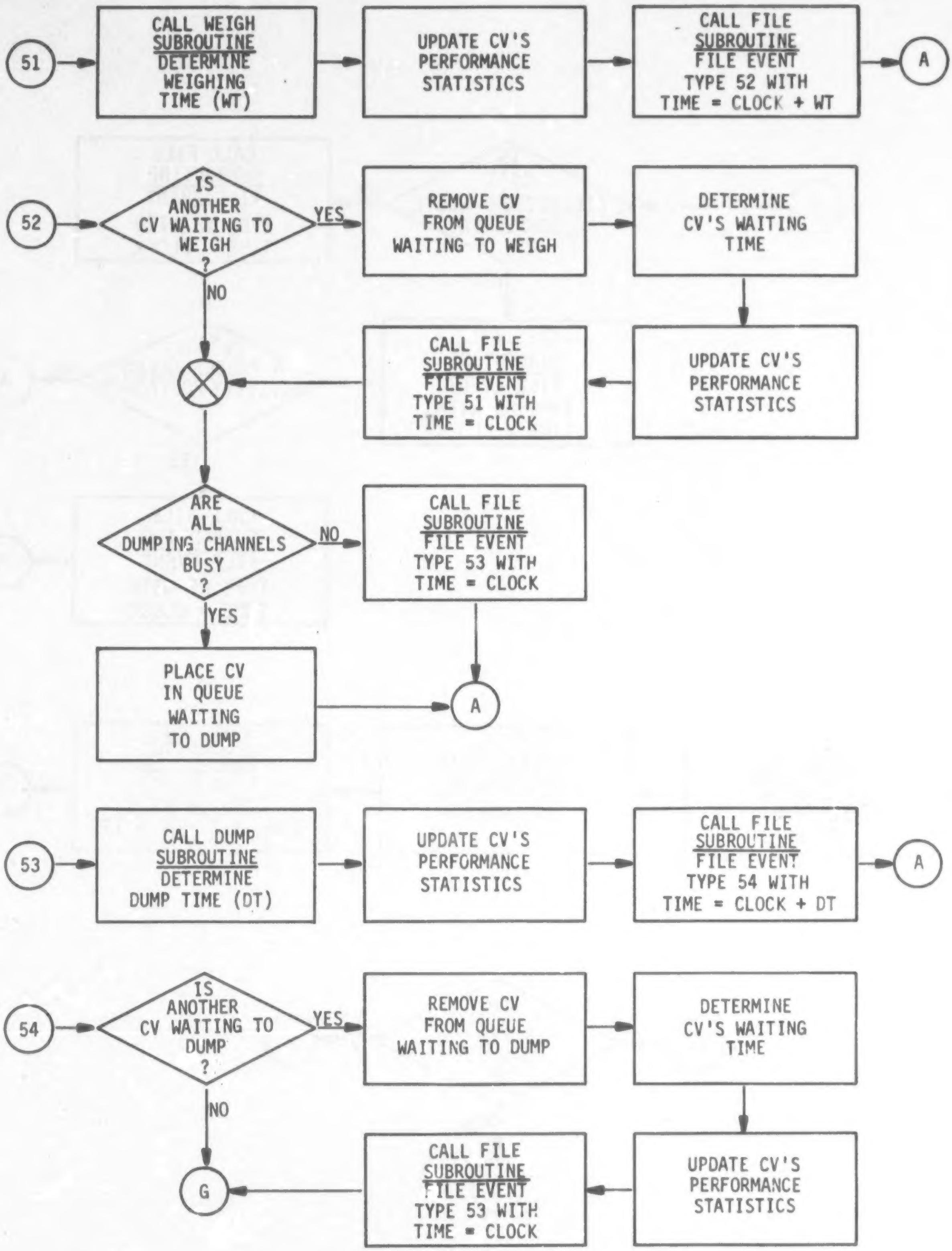
51
CALL WEIGH SUBROUTINE DETERMINE WEIGHING TIME (WT)
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 52 WITH TIME = CLOCK + WT
A
52
IS ANOTHER CV WAITING TO WEIGH ?
YES
NO
REMOVE CV FROM QUEUE WAITING TO WEIGH
DETERMINE CV'S WAITING TIME
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 51 WITH TIME = CLOCK
ARE ALL DUMPING CHANNELS BUSY ?
NO
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 53 WITH TIME = CLOCK
PLACE CV IN QUEUE WAITING TO DUMP
A
53
CALL DUMP SUBROUTINE DETERMINE DUMP TIME (DT)
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 54 WITH TIME = CLOCK + DT
A
54
IS ANOTHER CV WAITING TO DUMP ?
YES
NO
REMOVE CV FROM QUEUE WAITING TO DUMP
DETERMINE CV'S WAITING TIME
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 53 WITH TIME = CLOCK
G

Figure IV - 23

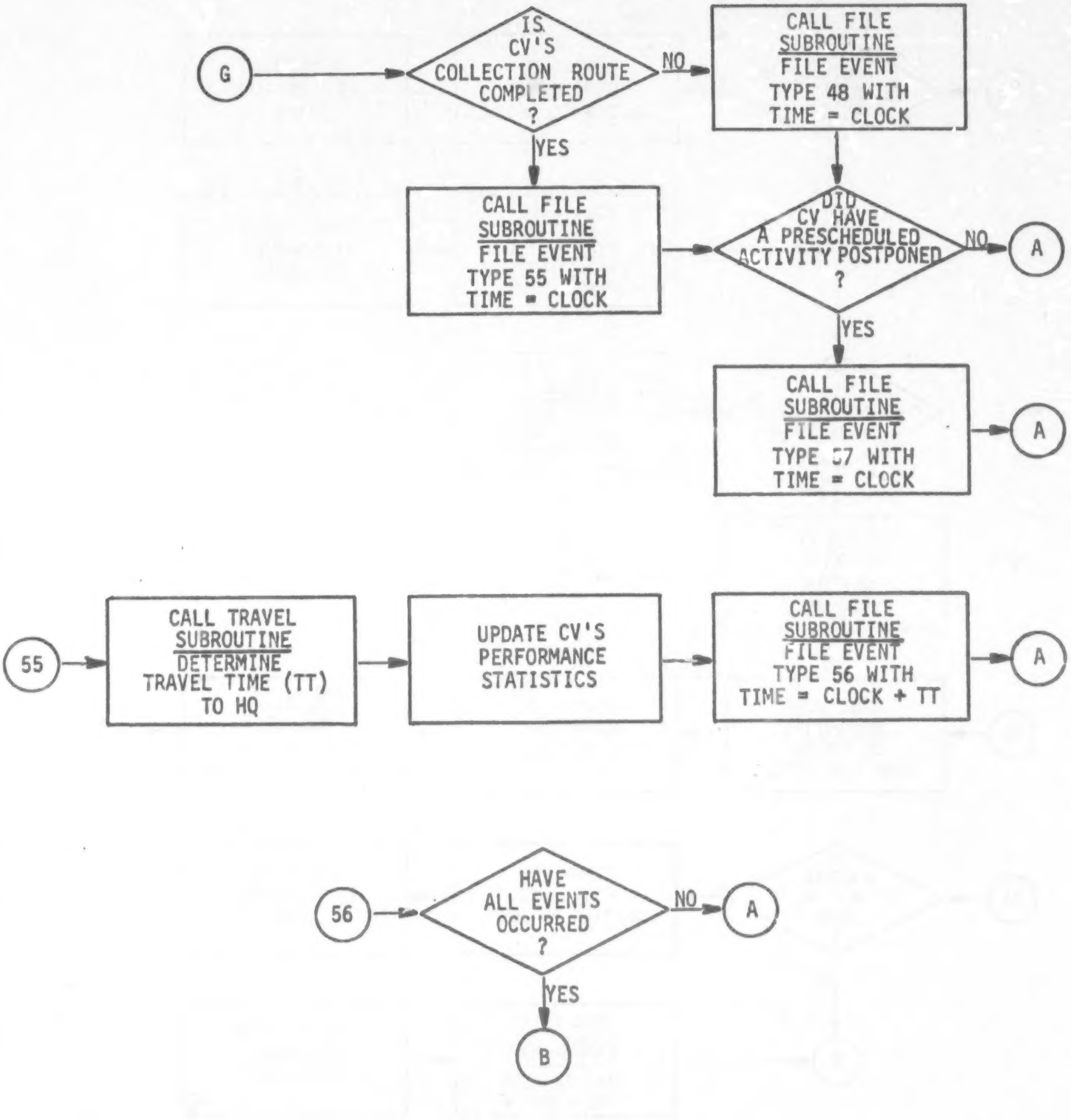
G
IS CV'S COLLECTION ROUTE COMPLETED ?
NO
CALL FILE SUBROUTINE
FILE EVENT TYPE 48 WITH TIME = CLOCK
YES
CALL FILE SUBROUTINE
FILE EVENT TYPE 55 WITH TIME = CLOCK
DID CV HAVE A PRESCHEDULED ACTIVITY POSTPONED ?
NO
A
YES
CALL FILE SUBROUTINE
FILE EVENT TYPE 57 WITH TIME = CLOCK
A
55
CALL TRAVEL SUBROUTINE
DETERMINE TRAVEL TIME (TT) TO HQ
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE
FILE EVENT TYPE 56 WITH TIME = CLOCK + TT
A
56
HAVE ALL EVENTS OCCURRED ?
NO
A
YES
B

Figure IV - 24

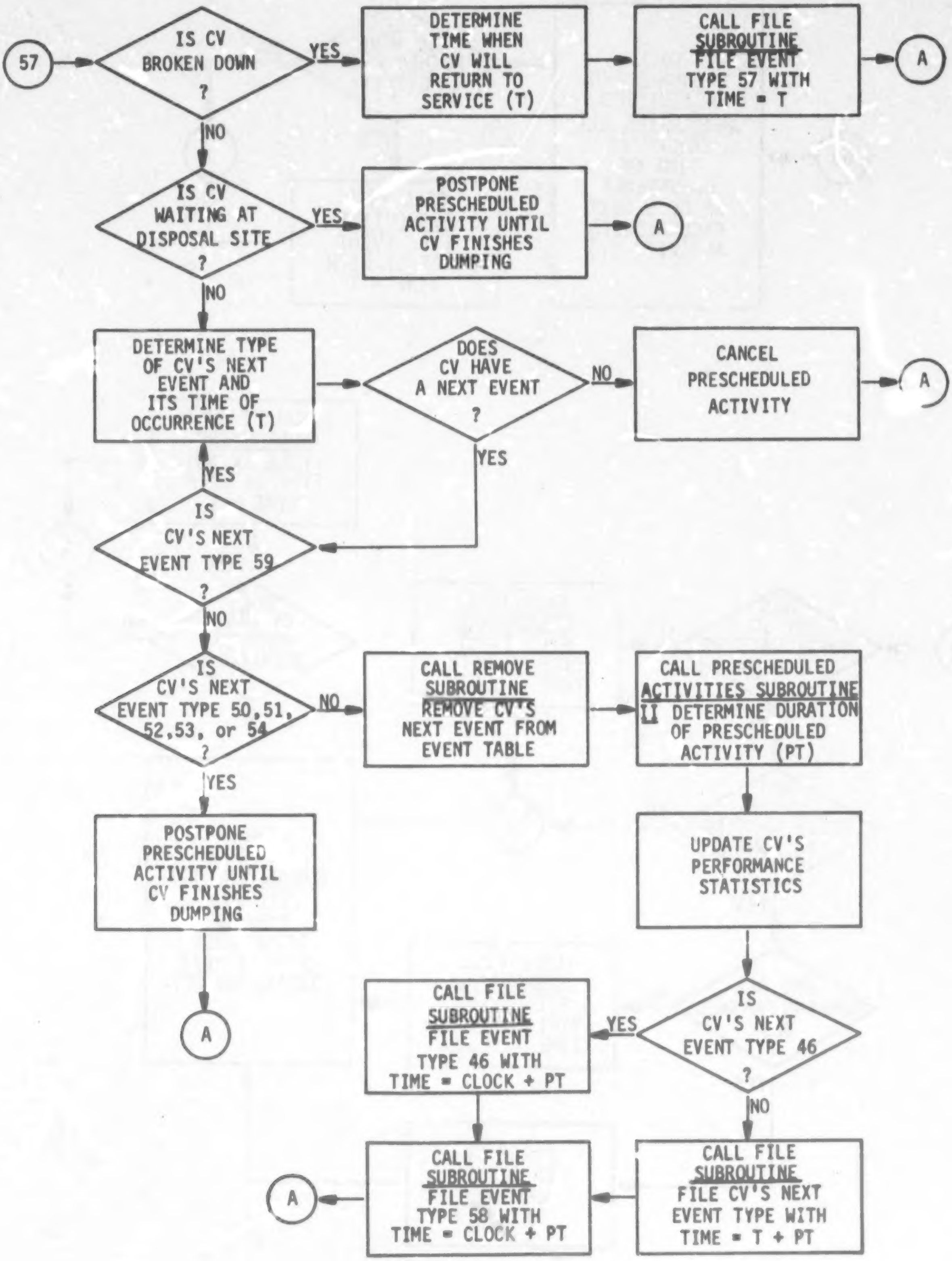
57
IS CV BROKEN DOWN ?
YES
DETERMINE TIME WHEN CV WILL RETURN TO SERVICE (T)
CALL FILE SUBROUTINE FILE EVENT TYPE 57 WITH TIME = T
A
NO
IS CV WAITING AT DISPOSAL SITE ?
YES
POSTPONE PRESCHEDULED ACTIVITY UNTIL CV FINISHES DUMPING
A
NO
DETERMINE TYPE OF CV'S NEXT EVENT AND ITS TIME OF OCCURRENCE (T)
DOES CV HAVE A NEXT EVENT ?
NO
CANCEL PRESCHEDULED ACTIVITY
A
YES
YES
IS CV'S NEXT EVENT TYPE 59 ?
NO
IS CV'S NEXT EVENT TYPE 50,51, 52,53, or 54 ?
NO
CALL REMOVE SUBROUTINE REMOVE CV'S NEXT EVENT FROM EVENT TABLE
CALL PRESCHEDULED ACTIVITIES SUBROUTINE II DETERMINE DURATION OF PRESCHEDULED ACTIVITY (PT)
YES
POSTPONE PRESCHEDULED ACTIVITY UNTIL CV FINISHES DUMPING
A
UPDATE CV'S PERFORMANCE STATISTICS
IS CV'S NEXT EVENT TYPE 46 ?
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 46 WITH TIME = CLOCK + PT
NO
CALL FILE SUBROUTINE FILE CV'S NEXT EVENT TYPE WITH TIME = T + PT
CALL FILE SUBROUTINE FILE EVENT TYPE 58 WITH TIME = CLOCK + PT
A

Figure IV - 25

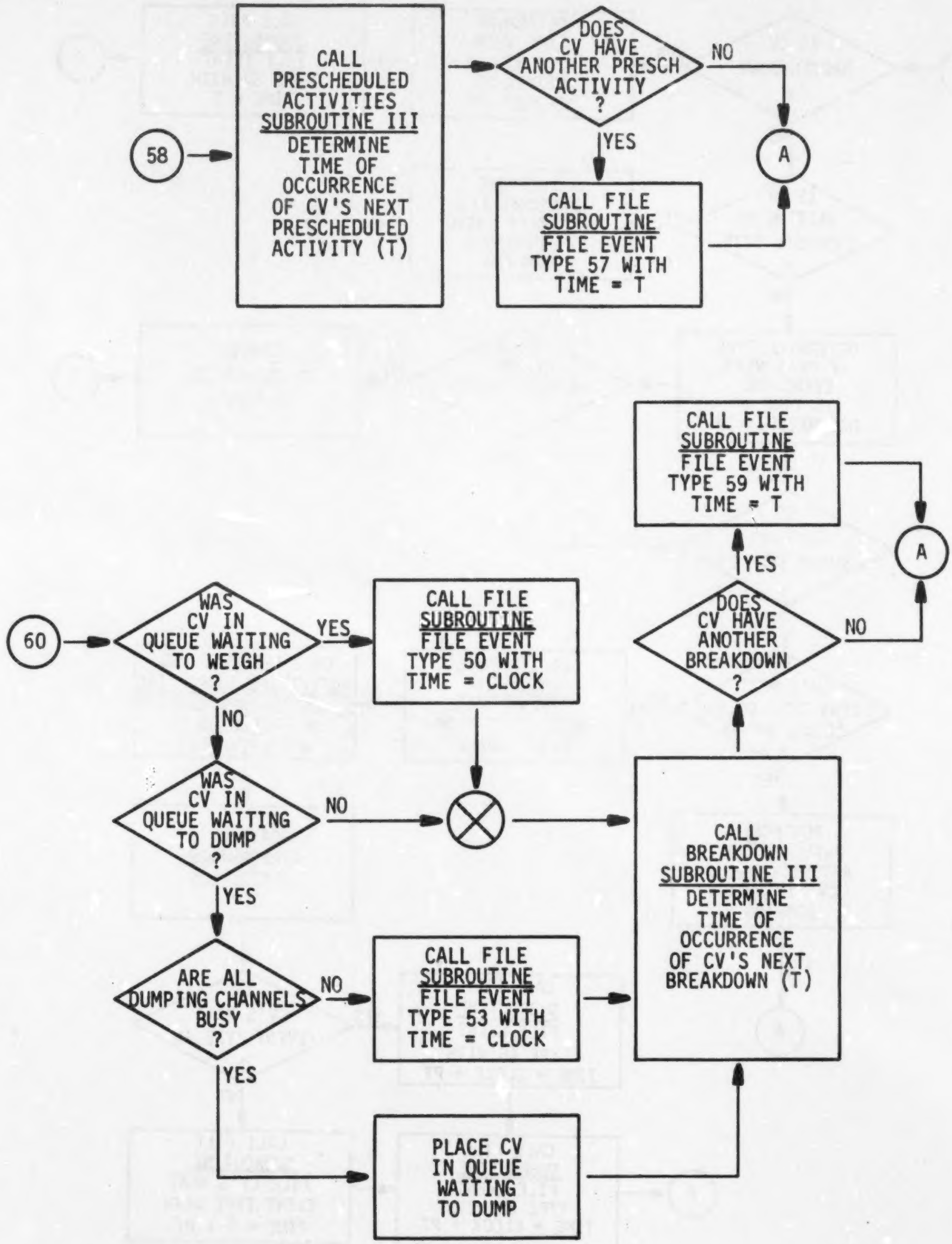
58
CALL PRESCHEDULED ACTIVITIES SUBROUTINE III
DETERMINE TIME OF OCCURRENCE OF CV'S NEXT PRESCHEDULED ACTIVITY (T)
DOES CV HAVE ANOTHER PRESCH ACTIVITY ?
NO
YES
CALL FILE SUBROUTINE
FILE EVENT TYPE 57 WITH TIME = T
A
CALL FILE SUBROUTINE
FILE EVENT TYPE 59 WITH TIME = T
YES
A
60
WAS CV IN QUEUE WAITING TO WEIGH ?
YES
CALL FILE SUBROUTINE
FILE EVENT TYPE 50 WITH TIME = CLOCK
DOES CV HAVE ANOTHER BREAKDOWN ?
NO
NO
WAS CV IN QUEUE WAITING TO DUMP ?
NO
CALL BREAKDOWN SUBROUTINE III
DETERMINE TIME OF OCCURRENCE OF CV'S NEXT BREAKDOWN (T)
YES
ARE ALL DUMPING CHANNELS BUSY ?
NO
CALL FILE SUBROUTINE
FILE EVENT TYPE 53 WITH TIME = CLOCK
YES
PLACE CV IN QUEUE WAITING TO DUMP

Figure IV - 26

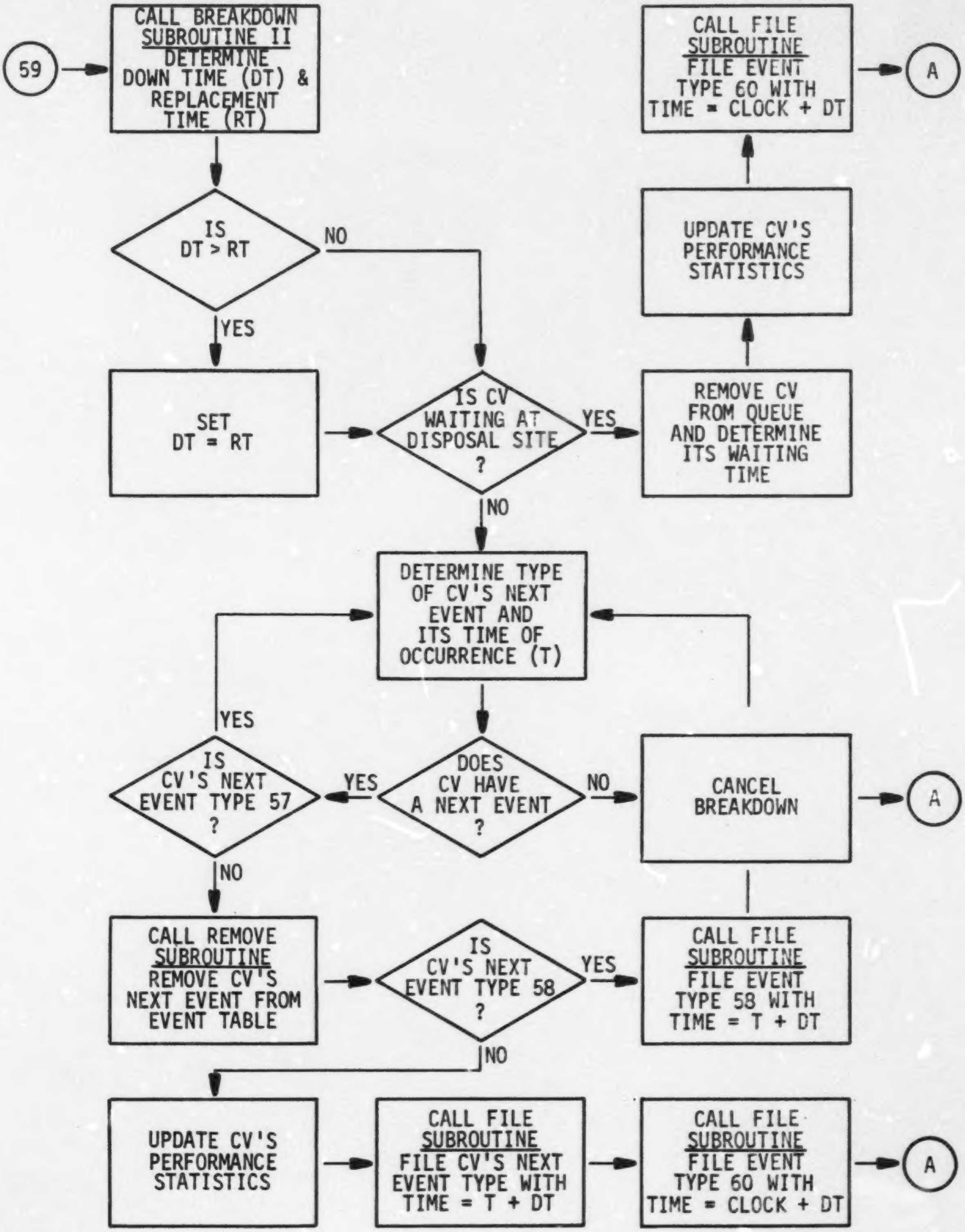
59
CALL BREAKDOWN SUBROUTINE II DETERMINE DOWN TIME (DT) & REPLACEMENT TIME (RT)
IS DT > RT
NO
YES
SET DT = RT
IS CV WAITING AT DISPOSAL SITE ?
YES
NO
REMOVE CV FROM QUEUE AND DETERMINE ITS WAITING TIME
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE EVENT TYPE 60 WITH TIME = CLOCK + DT
A
DETERMINE TYPE OF CV'S NEXT EVENT AND ITS TIME OF OCCURRENCE (T)
YES
IS CV'S NEXT EVENT TYPE 57 ?
YES
DOES CV HAVE A NEXT EVENT ?
NO
CANCEL BREAKDOWN
A
NO
CALL REMOVE SUBROUTINE REMOVE CV'S NEXT EVENT FROM EVENT TABLE
IS CV'S NEXT EVENT TYPE 58 ?
YES
CALL FILE SUBROUTINE FILE EVENT TYPE 58 WITH TIME = T + DT
NO
UPDATE CV'S PERFORMANCE STATISTICS
CALL FILE SUBROUTINE FILE CV'S NEXT EVENT TYPE WITH TIME = T + DT
CALL FILE SUBROUTINE FILE EVENT TYPE 60 WITH TIME = CLOCK + DT
A

Figure IV - 27

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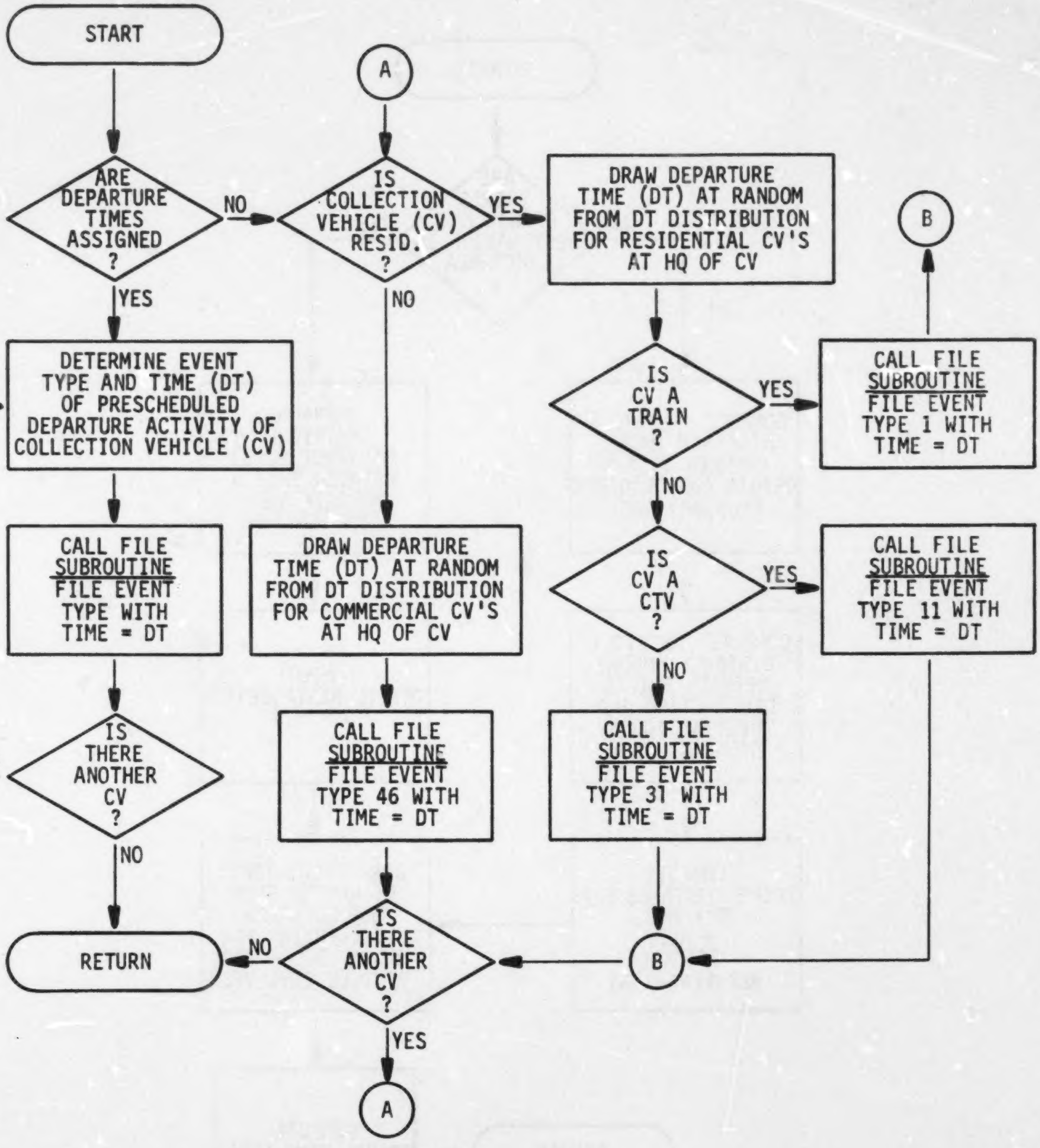
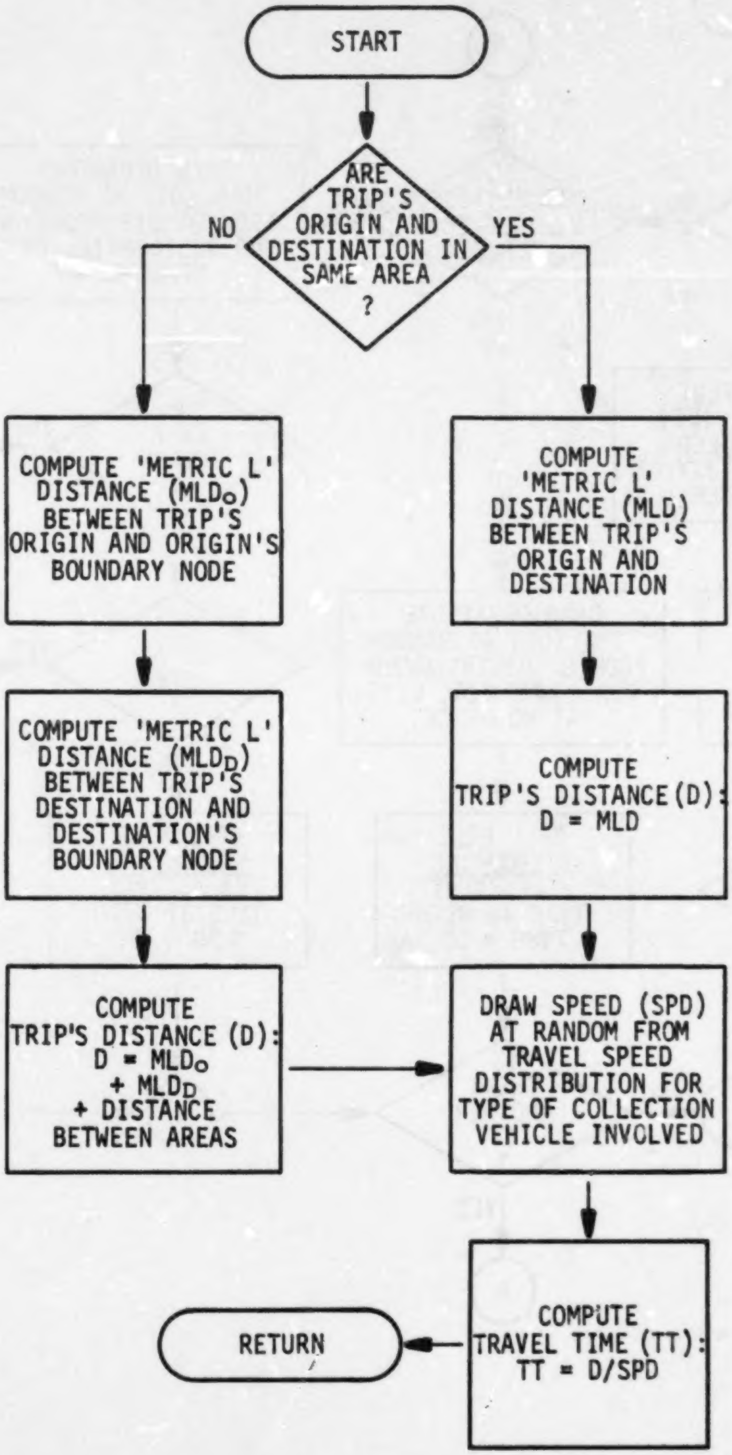
APPENDIX V

ACTIVITY SUBPROGRAM LOGIC FLOW CHARTS


START
ARE DEPARTURE TIMES ASSIGNED ?
NO
YES
DETERMINE EVENT TYPE AND TIME (DT) OF PRESCHEDULED DEPARTURE ACTIVITY OF COLLECTION VEHICLE (CV)
CALL FILE SUBROUTINE FILE EVENT TYPE WITH TIME = DT
IS THERE ANOTHER CV ?
YES
NO
RETURN
A
IS COLLECTION VEHICLE (CV) RESID. ?
YES
NO
DRAW DEPARTURE TIME (DT) AT RANDOM FROM DT DISTRIBUTION FOR COMMERCIAL CV'S AT HQ OF CV
CALL FILE SUBROUTINE FILE EVENT TYPE 46 WITH TIME = DT
IS THERE ANOTHER CV ?
NO
YES
A
DRAW DEPARTURE TIME (DT) AT RANDOM FROM DT DISTRIBUTION FOR RESIDENTIAL CV'S AT HQ OF CV
IS CV A TRAIN ?
YES
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 1 WITH TIME = DT
B
IS CV A CTV ?
YES
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 11 WITH TIME = DT
CALL FILE SUBROUTINE FILE EVENT TYPE 31 WITH TIME = DT
B

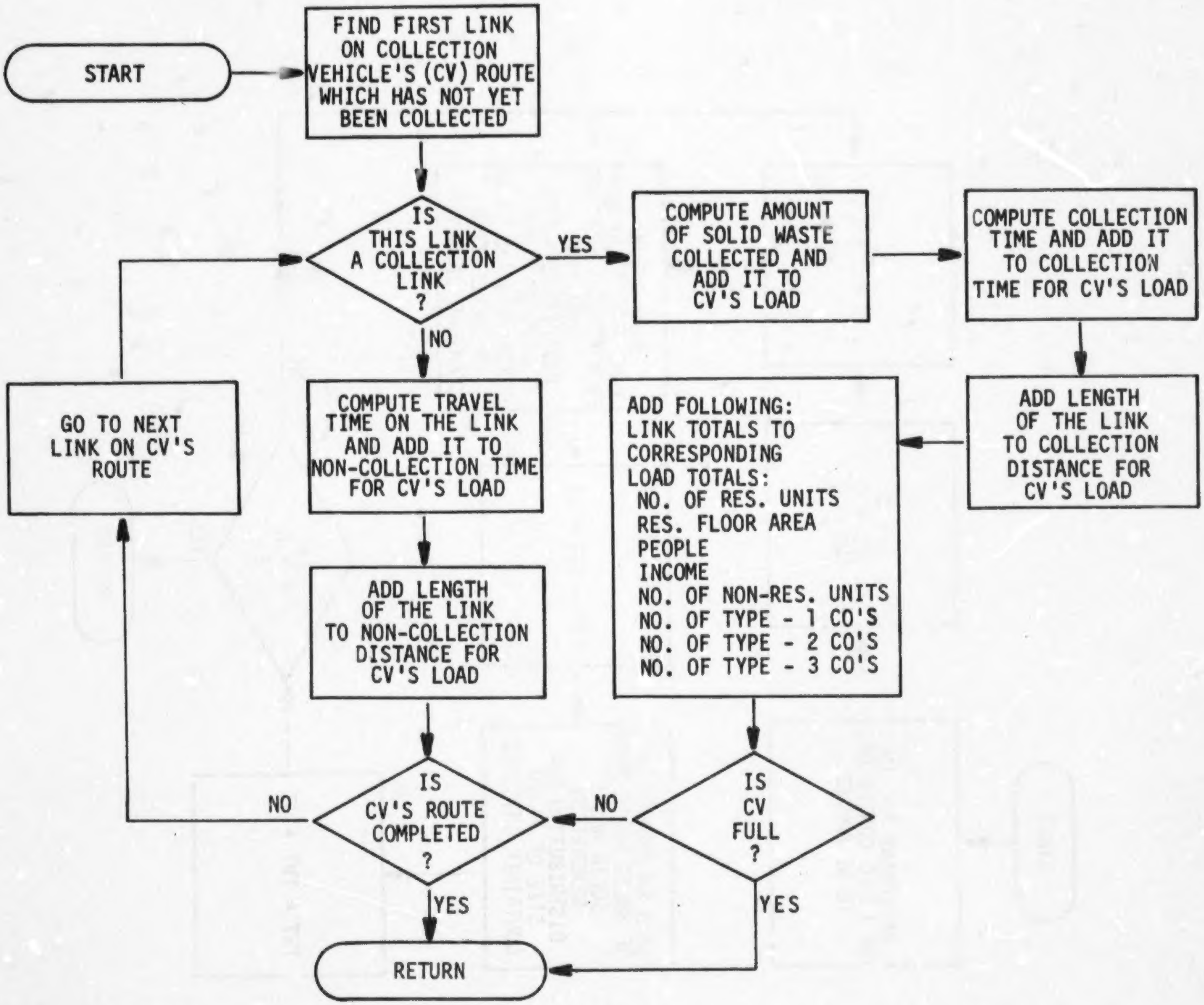
DEPARTURE SUBROUTINE LOGIC

Figure V - 1


START
ARE TRIP'S ORIGIN AND DESTINATION IN SAME AREA ?
NO
YES
COMPUTE 'METRIC L' DISTANCE (MLD$_O$) BETWEEN TRIP'S ORIGIN AND ORIGIN'S BOUNDARY NODE
COMPUTE 'METRIC L' DISTANCE (MLD$_D$) BETWEEN TRIP'S DESTINATION AND DESTINATION'S BOUNDARY NODE
COMPUTE TRIP'S DISTANCE (D): D = MLD$_O$ + MLD$_D$ + DISTANCE BETWEEN AREAS
COMPUTE 'METRIC L' DISTANCE (MLD) BETWEEN TRIP'S ORIGIN AND DESTINATION
COMPUTE TRIP'S DISTANCE (D): D = MLD
DRAW SPEED (SPD) AT RANDOM FROM TRAVEL SPEED DISTRIBUTION FOR TYPE OF COLLECTION VEHICLE INVOLVED
COMPUTE TRAVEL TIME (TT): TT = D/SPD
RETURN

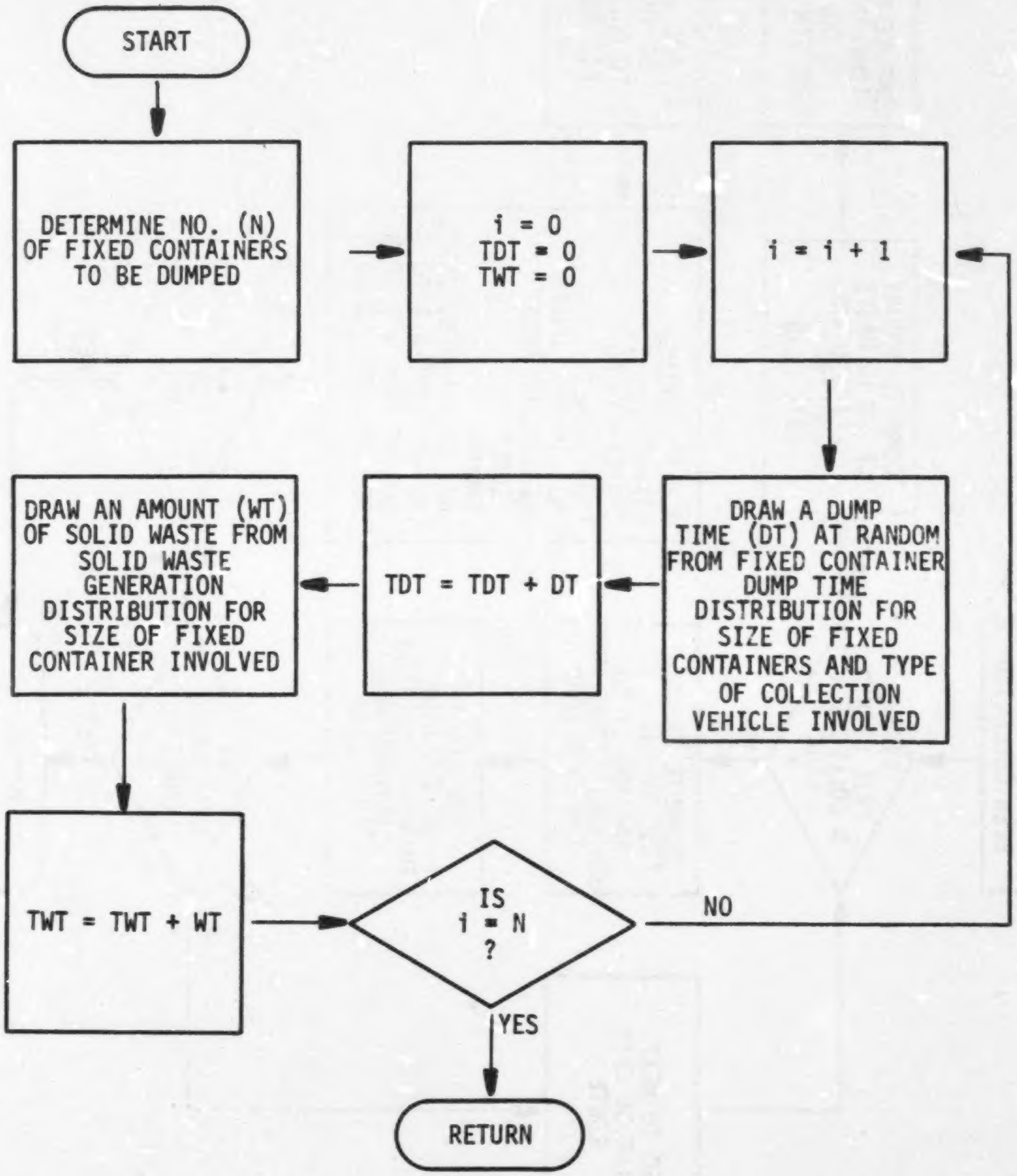
TRAVEL SUBROUTINE LOGIC

Figure V - 2


START
FIND FIRST LINK ON COLLECTION VEHICLE'S (CV) ROUTE WHICH HAS NOT YET BEEN COLLECTED
IS THIS LINK A COLLECTION LINK ?
YES
NO
COMPUTE AMOUNT OF SOLID WASTE COLLECTED AND ADD IT TO CV'S LOAD
COMPUTE COLLECTION TIME AND ADD IT TO COLLECTION TIME FOR CV'S LOAD
ADD LENGTH OF THE LINK TO COLLECTION DISTANCE FOR CV'S LOAD
ADD FOLLOWING: LINK TOTALS TO CORRESPONDING LOAD TOTALS:
NO. OF RES. UNITS
RES. FLOOR AREA
PEOPLE
INCOME
NO. OF NON-RES. UNITS
NO. OF TYPE - 1 CO'S
NO. OF TYPE - 2 CO'S
NO. OF TYPE - 3 CO'S
COMPUTE TRAVEL TIME ON THE LINK AND ADD IT TO NON-COLLECTION TIME FOR CV'S LOAD
ADD LENGTH OF THE LINK TO NON-COLLECTION DISTANCE FOR CV'S LOAD
GO TO NEXT LINK ON CV'S ROUTE
IS CV FULL ?
NO
YES
IS CV'S ROUTE COMPLETED ?
NO
YES
RETURN

COLLECTION SUBROUTINE I LOGIC

Figure V - 3


START
DETERMINE NO. (N) OF FIXED CONTAINERS TO BE DUMPED
i = 0
TDT = 0
TWT = 0
i = i + 1
DRAW A DUMP TIME (DT) AT RANDOM FROM FIXED CONTAINER DUMP TIME DISTRIBUTION FOR SIZE OF FIXED CONTAINERS AND TYPE OF COLLECTION VEHICLE INVOLVED
TDT = TDT + DT
DRAW AN AMOUNT (WT) OF SOLID WASTE FROM SOLID WASTE GENERATION DISTRIBUTION FOR SIZE OF FIXED CONTAINER INVOLVED
TWT = TWT + WT
IS i = N ?
NO
YES
RETURN

COLLECTION SUBROUTINE II LOGIC

Figure V - 4

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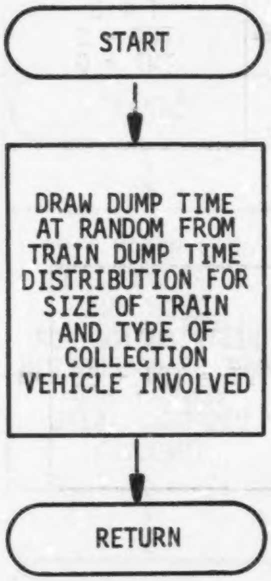
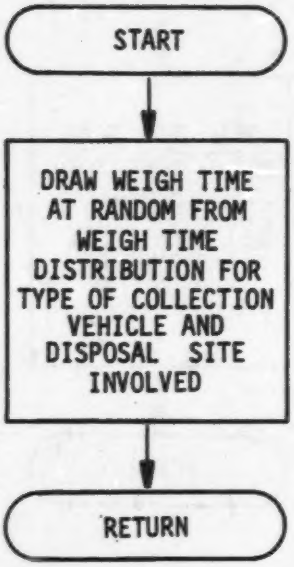
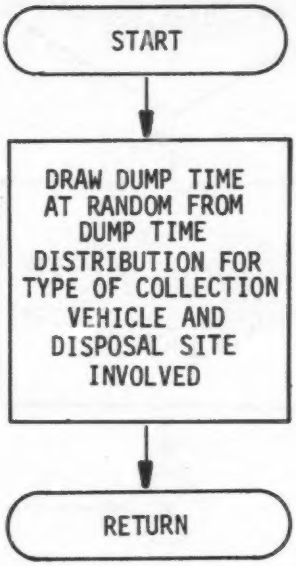

START
DRAW DUMP TIME AT RANDOM FROM TRAIN DUMP TIME DISTRIBUTION FOR SIZE OF TRAIN AND TYPE OF COLLECTION VEHICLE INVOLVED
RETURN

COLLECTION SUBROUTINE III LOGIC
Figure V - 5


START
DRAW WEIGH TIME AT RANDOM FROM WEIGH TIME DISTRIBUTION FOR TYPE OF COLLECTION VEHICLE AND DISPOSAL SITE INVOLVED
RETURN

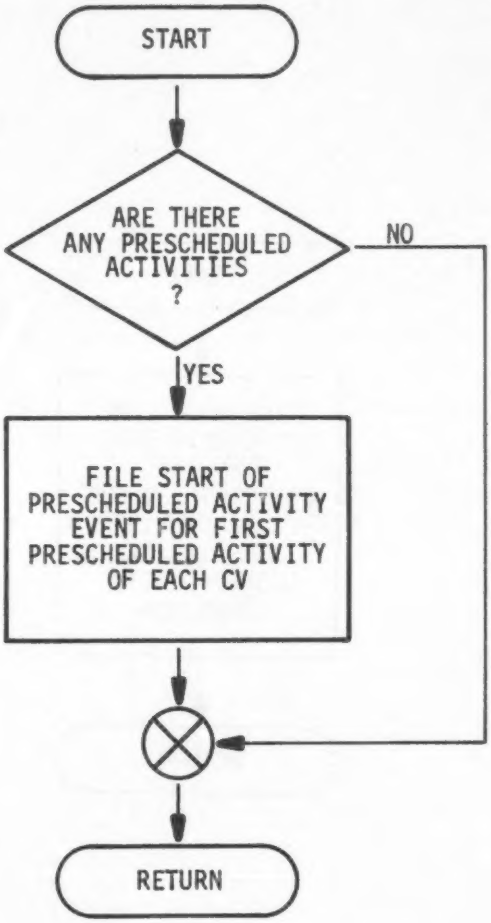
WEIGH SUBROUTINE LOGIC

Figure V - 6


START
DRAW DUMP TIME AT RANDOM FROM DUMP TIME DISTRIBUTION FOR TYPE OF COLLECTION VEHICLE AND DISPOSAL SITE INVOLVED
RETURN

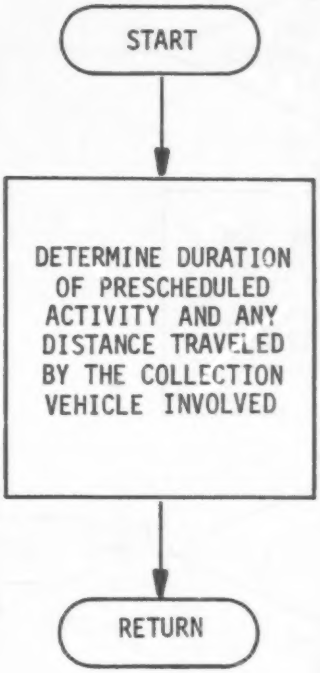
DUMP SUBROUTINE LOGIC

Figure V - 7


START
ARE THERE ANY PRESCHEDULED ACTIVITIES ?
NO
YES
FILE START OF PRESCHEDULED ACTIVITY EVENT FOR FIRST PRESCHEDULED ACTIVITY OF EACH CV
RETURN

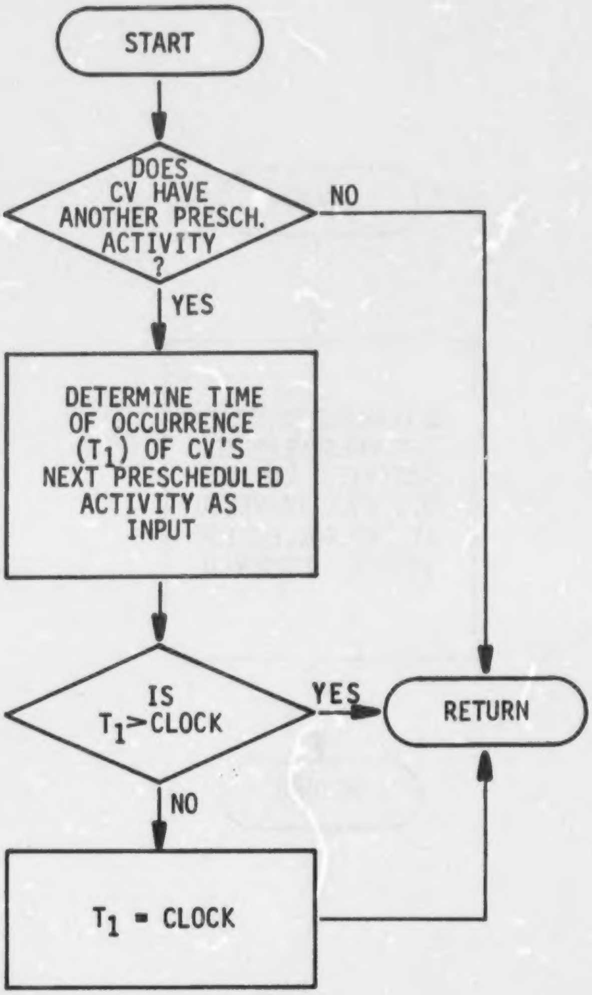
PRESCHEDULED ACTIVITIES SUBROUTINE I LOGIC

Figure V - 8


START
DETERMINE DURATION OF PRESCHEDULED ACTIVITY AND ANY DISTANCE TRAVELED BY THE COLLECTION VEHICLE INVOLVED
RETURN

PRESCHEDULED ACTIVITIES SUBROUTINE II LOGIC

Figure V - 9


START
DOES CV HAVE ANOTHER PRESCH. ACTIVITY ?
NO
YES
DETERMINE TIME OF OCCURRENCE (T_1) OF CV'S NEXT PRESCHEDULED ACTIVITY AS INPUT
IS T_1>CLOCK
YES
RETURN
NO
T_1 = CLOCK

PRESCHEDULED ACTIVITIES SUBROUTINE III LOGIC

Figure V - 10

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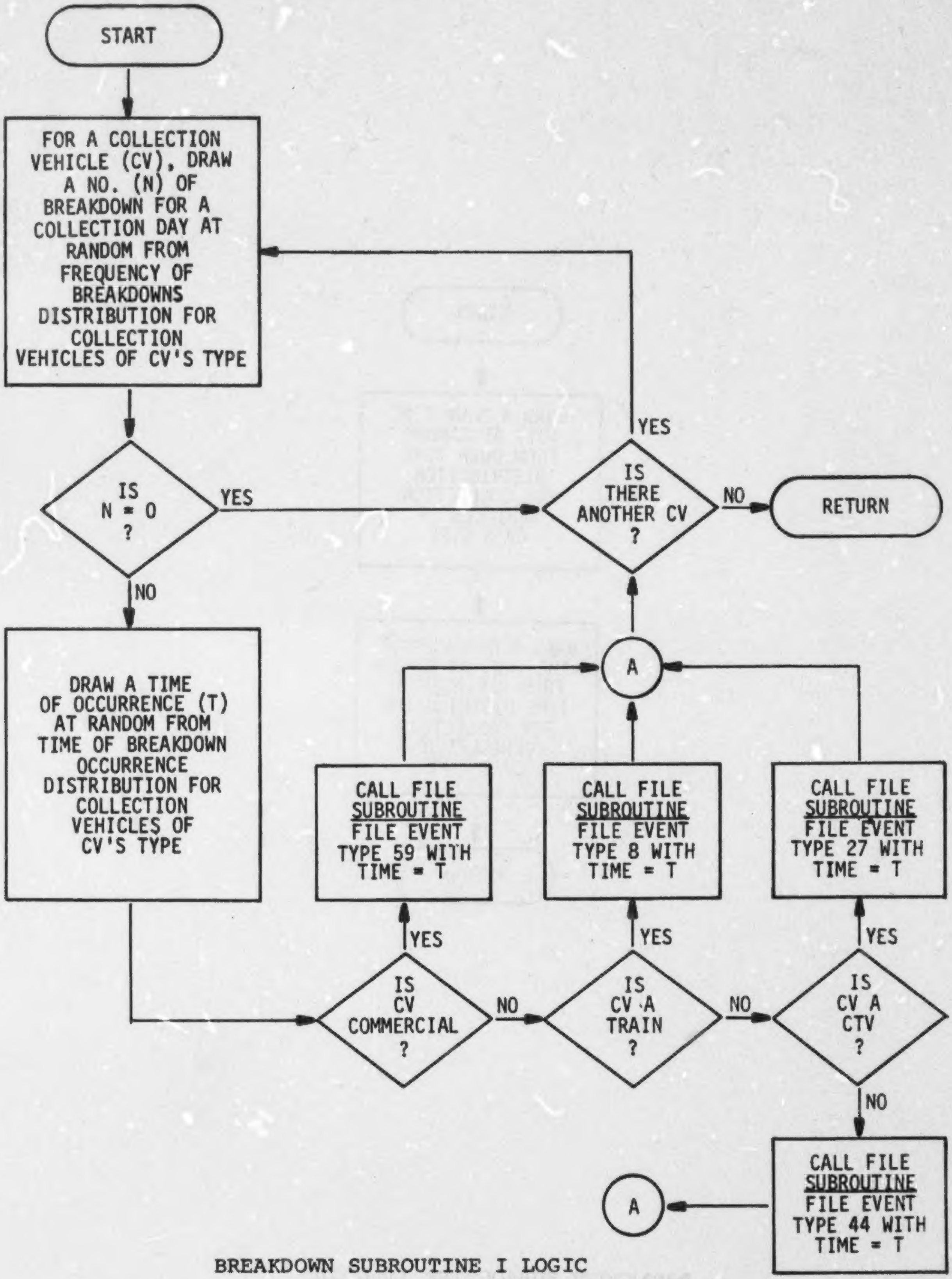
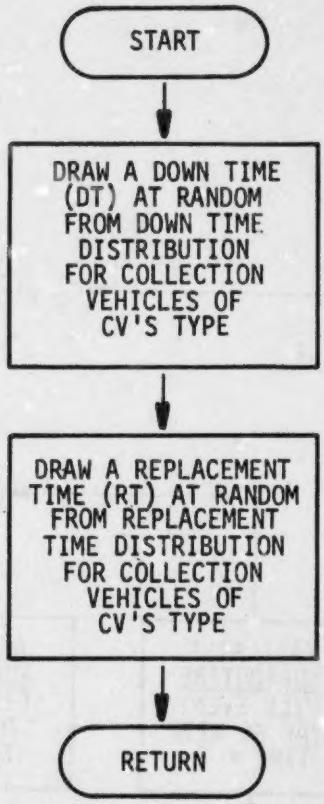

START
FOR A COLLECTION VEHICLE (CV), DRAW A NO. (N) OF BREAKDOWN FOR A COLLECTION DAY AT RANDOM FROM FREQUENCY OF BREAKDOWNS DISTRIBUTION FOR COLLECTION VEHICLES OF CV'S TYPE
IS N = 0 ?
YES
NO
IS THERE ANOTHER CV ?
YES
NO
RETURN
DRAW A TIME OF OCCURRENCE (T) AT RANDOM FROM TIME OF BREAKDOWN OCCURRENCE DISTRIBUTION FOR COLLECTION VEHICLES OF CV'S TYPE
A
CALL FILE SUBROUTINE FILE EVENT TYPE 59 WITH TIME = T
CALL FILE SUBROUTINE FILE EVENT TYPE 8 WITH TIME = T
CALL FILE SUBROUTINE FILE EVENT TYPE 27 WITH TIME = T
YES
YES
YES
IS CV COMMERCIAL ?
NO
IS CV A TRAIN ?
NO
IS CV A CTV ?
NO
CALL FILE SUBROUTINE FILE EVENT TYPE 44 WITH TIME = T
A

BREAKDOWN SUBROUTINE I LOGIC

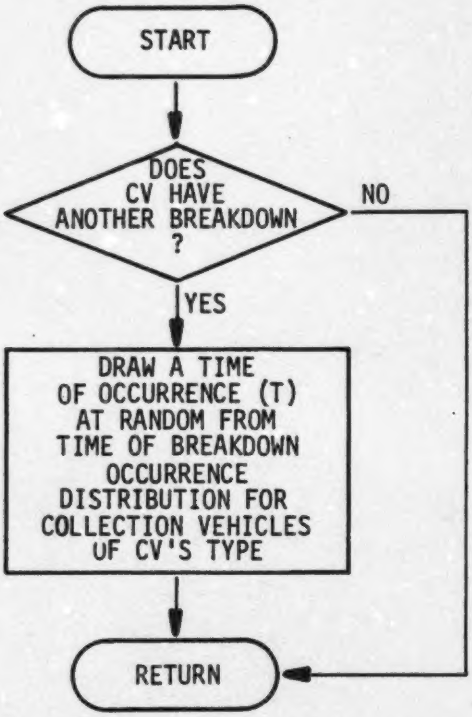
Figure V - 11

(213)


START
DRAW A DOWN TIME (DT) AT RANDOM FROM DOWN TIME DISTRIBUTION FOR COLLECTION VEHICLES OF CV'S TYPE
DRAW A REPLACEMENT TIME (RT) AT RANDOM FROM REPLACEMENT TIME DISTRIBUTION FOR COLLECTION VEHICLES OF CV'S TYPE
RETURN

BREAKDOWN SUBROUTINE II LOGIC

Figure V - 12


START
DOES CV HAVE ANOTHER BREAKDOWN ?
NO
YES
DRAW A TIME OF OCCURRENCE (T) AT RANDOM FROM TIME OF BREAKDOWN OCCURRENCE DISTRIBUTION FOR COLLECTION VEHICLES OF CV'S TYPE
RETURN

BREAKDOWN SUBROUTINE III LOGIC

Figure V - 13

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APPENDIX VI

UTILITY SUBPROGRAM LOGIC FLOW CHARTS

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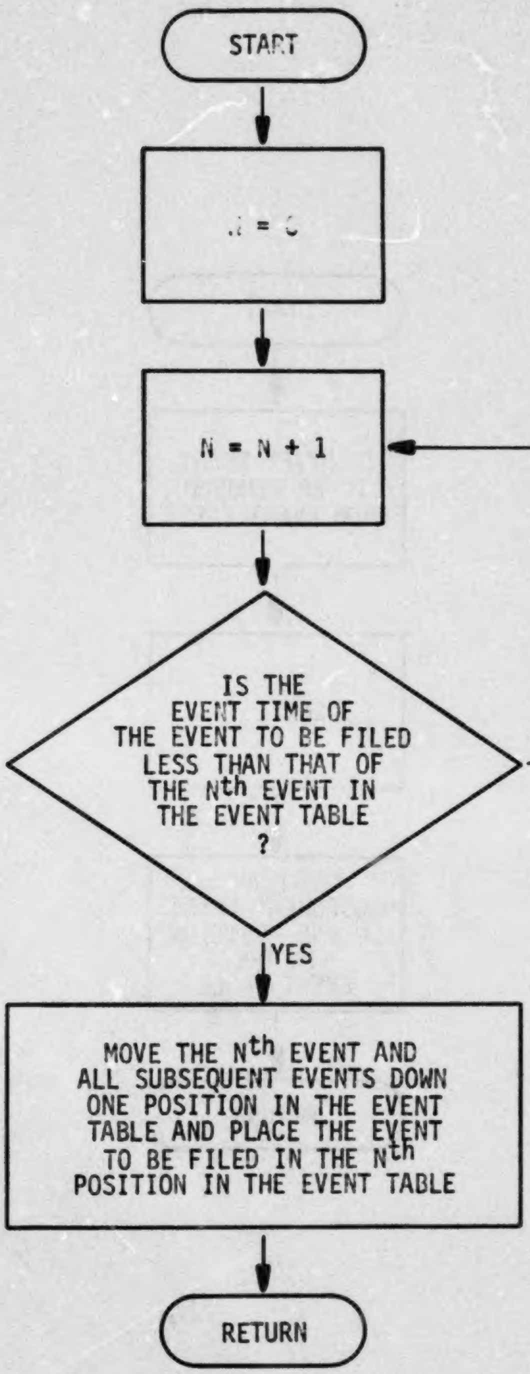
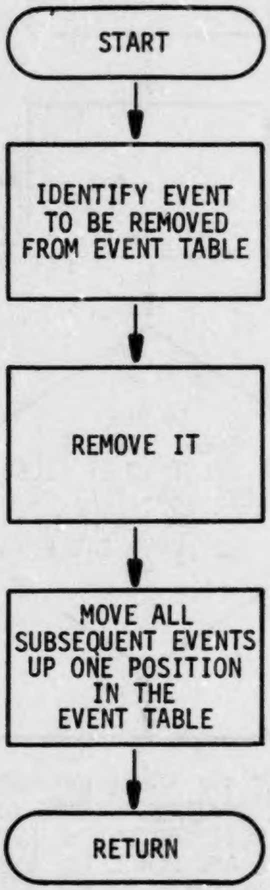

START
N = 0
N = N + 1
IS THE EVENT TIME OF THE EVENT TO BE FILED LESS THAN THAT OF THE N^th EVENT IN THE EVENT TABLE ?
NO
YES
MOVE THE N^th EVENT AND ALL SUBSEQUENT EVENTS DOWN ONE POSITION IN THE EVENT TABLE AND PLACE THE EVENT TO BE FILED IN THE N^th POSITION IN THE EVENT TABLE
RETURN

FILE SUBROUTINE LOGIC

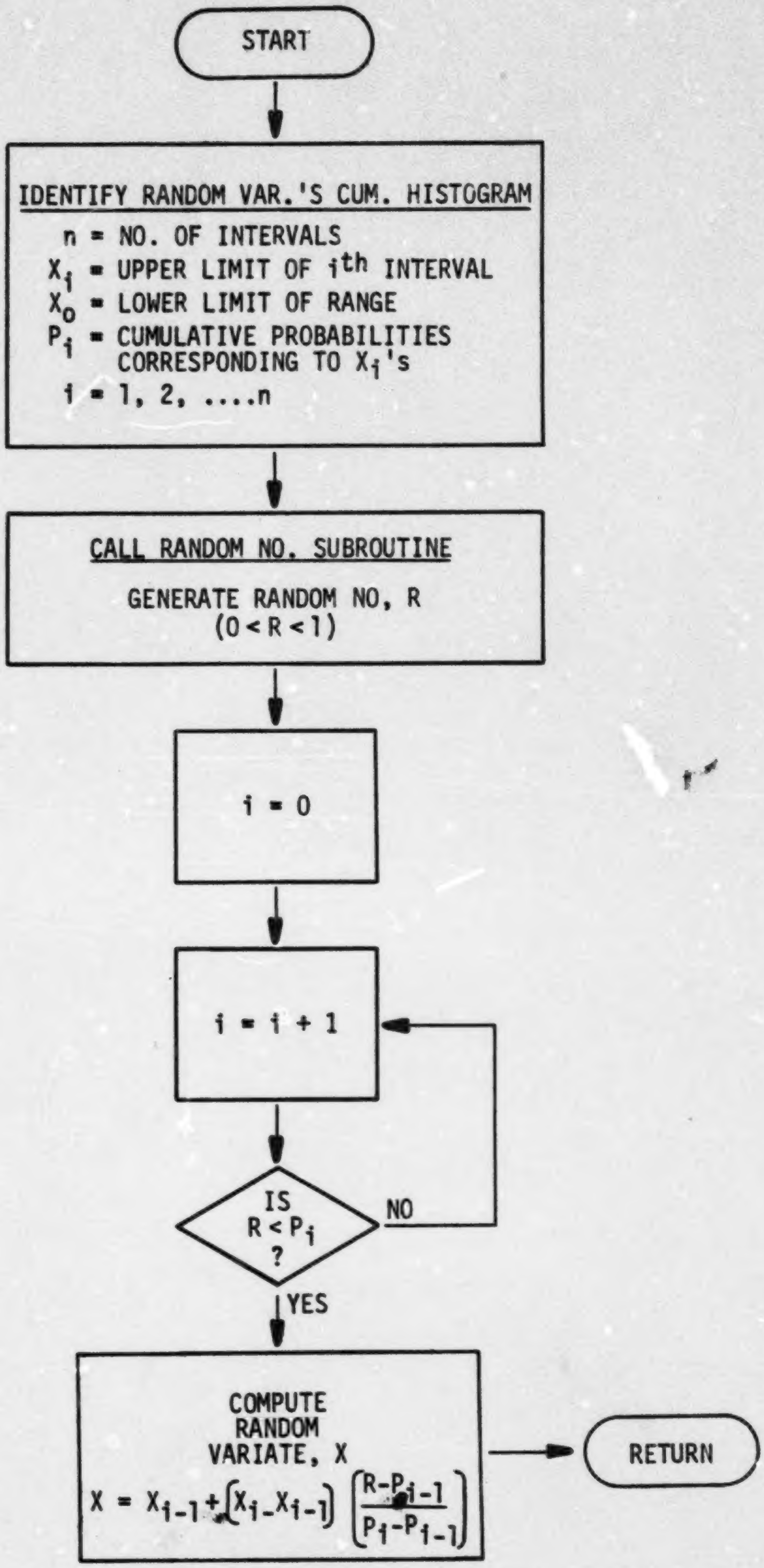
Figure VI - 1


START
IDENTIFY EVENT TO BE REMOVED FROM EVENT TABLE
REMOVE IT
MOVE ALL SUBSEQUENT EVENTS UP ONE POSITION IN THE EVENT TABLE
RETURN

REMOVE SUBROUTINE LOGIC

Figure VI - 2

218


START
IDENTIFY RANDOM VAR.'S CUM. HISTOGRAM
n = NO. OF INTERVALS
X_i = UPPER LIMIT OF i^{th} INTERVAL
X_o = LOWER LIMIT OF RANGE
P_i = CUMULATIVE PROBABILITIES CORRESPONDING TO X_i's
$i = 1, 2, \ldots .n$
CALL RANDOM NO. SUBROUTINE
GENERATE RANDOM NO, R
$(0 < R < 1)$
$i = 0$
$i = i + 1$
IS $R < P_i$?
NO
YES
COMPUTE RANDOM VARIATE, X
$X = X_{i-1} + \left(X_i - X_{i-1}\right)\left(\frac{R - P_{i-1}}{P_i - P_{i-1}}\right)$
RETURN

HISTOGRAM SUBROUTINE LOGIC
Figure VI - 3

APPENDIX VII

OUTPUT PROGRAM MODULE REPORTS

```
                    SOLID WASTE COLLECTION SYSTEM SIMULATION

          TEST SIMULATION RUN FOR PILOT STUDY AREA NO. 3 - MAY 1973

COLLECTION DATE                                       NO. OF SIMULATION ITERATIONS    4

   MONTH   07
   NO. DAYS SINCE LAST COLLECTION    4                NO. OF STREET NETWORK AREAS    1

                  H E A D Q U A R T E R S


                                                  STREET
                 C O O R D I N A T E S            NETWORK
        ID NO.          X          Y              AREA NO.

          1          17931       6431                1


                             D I S P O S A L   S I T E S

                                                  STREET                        NO. OF
                 C O O R D I N A T E S            NETWORK      NO. OF           DUMPING
        ID NO.          X          Y              AREA NO.     SCALES           CHANNELS

          1           1495      63138                1            1                 6
          2         111247        462                1            1                 8
```

SYSTEM DESCRIPTION REPORT

FIGURE VII - I

```
RESIDENTIAL COLLECTION SYSTEM

  TYPE   CONTAINER-TRAIN SYSTEM                                  TYPE OF CONTAINER   CAN

  COLLECTION VEHICLES

      TRAIN    CAPACITY    CREW     CONVOY    HQ.    DISPOSAL     COLLECTION ROUTE
       NO.       (LBS)     SIZE       NO.     NO.    SITE NO.     FROM          TO

       001       2500       3         01       1        1         0001         0157
       002       2500       3         01       1        1         0158         0299
       003       2500       3         01       1        1         0300         0472
       004       2500       3         01       1        1         0473         0641
       005       2500       3         02       1        1         0642         0793
       006       2500       3         02       1        1         0794         0970
       007       2500       3         02       1        1         0971         1127
       008       2500       3         02       1        1         1128         1278
```

SYSTEM DESCRIPTION REPORT

FIGURE VII - I (CONT'D)

```
CTV    CAPACITY   CREW    CONVOY    HQ.    DISPOSAL     COLLECTION ROUTE
NO.     (LBS)     SIZE     NO.      NO.    SITE NO.     FROM          TO

009      9000      1       01        1        2         0001        0028
010      9000      1       02        1        2         0029        0048
```

SYSTEM DESCRIPTION REPORT

FIGURE VII - I (CONT'D)

```
TYPE   PACKER TRUCK SYSTEM                          TYPE OF CONTAINER   CAN

COLLECTION VEHICLES

     TRUCK      CAPACITY    CREW    HQ.    DISPOSAL    COLLECTION ROUTE
      NO.        (LBS)      SIZE    NO.    SITE NO.    FROM           TO

      001        10000       3       1        2        0001          0187
      002        10000       3       1        2        0188          0290
      003        10000       3       1        2        0291          0453
      004        10000       3       1        2        0454          0667
```

SYSTEM DESCRIPTION REPORT

FIGURE VII - I (CONT'D)

```
COMMERCIAL COLLECTION SYSTEM

   TYPE   CONTAINER TRANSFER VEHICLE SYSTEM

   COLLECTION VEHICLES

          CTV      CAPACITY   CREW    HQ.    DISPOSAL    COLLECTION ROUTE
          NO.       (LBS)     SIZE    NO.    SITE NO.    FROM          TO

          011       10000      1       1        2        0115         0247
          012       10000      1       1        2        0248         0361
          013       10000      1       1        2        0362         0496
```

SYSTEM DESCRIPTION REPORT

FIGURE VII - I (CONT'D)

```
TYPE    PACKER TRUCK SYSTEM

COLLECTION VEHICLES

        TRUCK     CAPACITY    CREW    HQ.    DISPOSAL    COLLECTION ROUTE
         NO.       (LBS)      SIZE    NO.    SITE NO.    FROM          TO

         015       10000        2      1         2       0315         0411
         016       10000        2      1         2       0412         0507
```

SYSTEM DESCRIPTION REPORT

FIGURE VII - I (CONT'D)

```
OPTIONAL TRAVEL SPEEDS INPUT

 CV    DIST  MINIMUM   MAXIMUM   NO. OF
TYPE   CODE   VALUE     VALUE    INTVLS  CUMULATIVE   PROBABILITIES

  1      1     250      1250       5     .20   .50    .70   .90   1.00

  1      2    1000      2000       5     .30   .60    .85   .95   1.00

  5      1    1500      3000       5     .25   .30    .75   .85   1.00

  5      2    2500      5000       5     .10   .20    .50   .80   1.00
```

SYSTEM DESCRIPTION REPORT

FIGURE VII - 1 (CONT'D)

```
OPTIONAL SOLID WASTE GENERATION RATES INPUT

        MINIMUM     MAXIMUM   NO. OF
CODE     VALUE       VALUE    INTVLS  CUMULATIVE PROBABILITIES

01           5         25       4      .25  .50  .75 1.00
```

SYSTEM DESCRIPTION REPORT

FIGURE VII - 1 (CONT'D)

PRESCHEDULED ACTIVITIES

COLLECTION VEHICLE NO.	SEQ. NO.	TIME OF OCCURRENCE	DURATION	DISTANCE TRAVELED
009	1	720	30	2.0
010	1	720	30	2.0

SYSTEM DESCRIPTION REPORT

FIGURE VII - 1 (CONT'D)

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```
TIME      E V E N T


1247    TRAIN NO. 002 STARTS TO COLLECT AT NODE NO.   13172.
            AMOUNT OF SOLID WASTE COLLECTED =   2491 LBS.
            COLLECTION TIME =   1.40 HOURS
            COLLECTION DISTANCE =   1.95 MILES
            NON-COLLECTION TIME =   0.15 HOURS
            NON-COLLECTION DISTANCE =   2.59 MILES
            AVG. FLOOR AREA PER RESIDENTIAL UNIT SERVED =   1349 SQ.FT.
            AVG. NO. OF PEOPLE PER RESIDENTIAL UNIT SERVED =   3.68
            AVG. INCOME PER RESIDENTIAL UNIT SERVED =      0
            NO. OF TYPE-ONE CARRY OUTS =    0
            NO. OF TYPE-TWO CARRY OUTS =    0
            NO. OF TYPE-THREE CARRY OUTS =     0



1249    CTV NO. 009 DUMPS TRAIN NO. 001 WHICH HAS BEEN WAITING AT
        NODE NO.   10709 FOR  0.15 HOURS
            AMOUNT OF SOLID WASTE COLLECTED =   2358 LBS.
            COLLECTION TIME =   0.10 HOURS

1249    TRAIN NO. 007 CALLS CTV NO. 010 AND STARTS TO WAIT AT NODE NO.   25692

1259    CTV NO.009 TRAVELS FROM NODE NO.   10709 TO DISPOSAL SITE NO. 2.
            TRAVEL TIME =  0.15 HOURS
            TRAVEL DISTANCE =   2.43 MILES
```

EVENT LISTING

FIGURE VII - 2

```
                         DISPOSAL SITE REPORT

DISPOSAL SITE NO. 2          X-COORDINATE       111247, Y-COORDINATE        462

STREET NETWORK AREA NO. 1     NO. OF SCALES   1     NO. OF DUMPING CHANNELS     8

              AVERAGE     AVERAGE                                          AVERAGE
               TOTAL       TOTAL                                        TOTAL AMOUNT
COLLECTION   WEIGHING      DUMP       AVERAGE TOTAL WAITING TIME         OF SOLID
  VEHICLE      TIME        TIME       AT SCALES   TO DUMP     TOTAL     WASTE DUMPED
    NO.      (HOURS)     (HOURS)      (HOURS)    (HOURS)    (HOURS)       (LBS)

    009        0.20        1.05         0.10       0.00       0.10        78532

    010        0.25        1.12         0.15       0.00       0.15        56976

    011        0.15        1.15         0.05       0.00       0.05        87963

    012        0.28        1.38         0.10       0.00       0.10        64795

    013        0.15        1.25         0.20       0.00       0.20        75855

   TOTAL       1.03        5.95         0.60       0.00       0.60       364021


AVERAGE TOTAL NO. OF ARRIVALS                                                46

AVERAGE WEIGHING QUEUE
   MAXIMUM LENGTH                                                            3.0
   AVERAGE LENGTH                                                            0.8

AVERAGE DUMPING QUEUE
   MAXIMUM LENGTH                                                            0.0
   AVERAGE LENGTH                                                            0.0
```

DISPOSAL SITE REPORT

FIGURE VII - 3

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```
TRAIN REPORT

   TRAIN NO.   1           CAPACITY     2500 LBS.                NO. OF CONTAINERS    4

   CREW SIZE   3           CTV NO. 009                           CONVOY NO. 01

   HQ. NO. 1               COLLECTION ROUTE     FROM LINK NO. 0001  TO LINK NO. 0157

AVERAGE TOTAL LENGTH OF COLLECTION DAY                                  8.30 HOURS
   AVERAGE TRAVEL TIME                                                  0.60 HOURS
   AVERAGE COLLECTION TIME                                              4.90 HOURS
   AVERAGE NON-COLLECTION TIME                                          0.55 HOURS
   AVERAGE DUMP TIME                                                    0.58 HOURS
   AVERAGE WAITING TIME                                                 1.67 HOURS
   AVERAGE PRESCHEDULED ACTIVITY TIME                                   0.00 HOURS
   AVERAGE DOWN TIME                                                    0.00 HOURS

AVERAGE TOTAL DISTANCE TRAVELED                                        23.55 MILES
   AVERAGE TRAVEL DISTANCE                                             10.14 MILES
   AVERAGE COLLECTION DISTANCE                                          6.39 MILES
   AVERAGE NON-COLLECTION DISTANCE                                      7.02 MILES
   AVERAGE PRESCHEDULED ACTIVITY DISTANCE                               0.00 MILES

AVERAGE TOTAL NO. OF RESIDENTIAL UNITS SERVED                           634
   AVERAGE FLOOR AREA PER RESIDENTIAL UNIT SERVED                      1316 SQ. FT.
   AVERAGE NO. OF PEOPLE PER RESIDENTIAL UNIT SERVED                    4.34
   AVERAGE INCOME PER RESIDENTIAL UNIT SERVED                        $ 9220

AVERAGE TOTAL NO. OF CARRY OUTS                                          115
   AVERAGE NO. OF TYPE-ONE CARRY OUTS                                     55
   AVERAGE NO. OF TYPE-TWO CARRY OUTS                                     43
   AVERAGE NO. OF TYPE-THREE CARRY OUTS                                   17


AVERAGE TOTAL NO. OF DUMPS                                               5.9


AVERAGE TOTAL AMOUNT OF SOLID WASTE COLLECTED                          15458 LBS.


AVERAGE TOTAL TRAIN MILES                                              23.55


AVERAGE TOTAL TRAIN HOURS                                               8.30


AVERAGE TOTAL TRAIN MANHOURS                                           24.90
```

TRAIN REPORT

FIGURE VII - 4

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CTV REPORT

   CTV NO. 009             CAPACITY     9000 LBS.             CREW SIZE   1

   TRAIN NOS.   001, 002, 003, 004

   CONVOY NO. 01           HQ. NO. 1                          DISPOSAL SITE NO. 2

   COLLECTION ROUTE   FROM COLLECTION UNIT NO. 0001 TO COLLECTION UNIT NO. 0028

AVERAGE TOTAL LENGTH OF COLLECTION DAY                              10.91 HOURS
   AVERAGE TRAVEL TIME                                               4.26 HOURS
   AVERAGE COLLECTION TIME                                           3.40 HOURS
   AVERAGE WEIGHING TIME                                             0.20 HOURS
   AVERAGE DUMP TIME                                                 1.05 HOURS
   AVERAGE TIME WAITING TO DUMP TRAINS                               1.90 HOURS
   AVERAGE TIME WAITING AT DISPOSAL SITE                             0.10 HOURS
      AVERAGE TIME WAITING AT SCALES                                 0.10 HOURS
      AVERAGE TIME WAITING TO DUMP                                   0.00 HOURS
   AVERAGE PRESCHEDULED ACTIVITY TIME                                0.00 HOURS
   AVERAGE DOWN TIME                                                 0.00 HOURS

AVERAGE TOTAL DISTANCE TRAVELED                                     91.90 MILES
   AVERAGE TRAVEL DISTANCE                                          91.90 MILES
   AVERAGE PRESCHEDULED ACTIVITY DISTANCE                            9.00 MILES

AVERAGE TOTAL NO. OF TRIPS TO DISPOSAL SITE                           8.0


AVERAGE TOTAL NO. OF TRAINS DUMPED                                   24.2


AVERAGE TOTAL NO. OF FIXED CONTAINERS DUMPED                          34


AVERAGE TOTAL AMOUNT OF SOLID WASTE COLLECTED                       78532 LBS.
   AVERAGE AMOUNT COLLECTED FROM TRAINS                             67751 LBS.
   AVERAGE AMOUNT COLLECTED FROM FIXED CONTAINERS                   10781 LBS.


AVERAGE TOTAL CTV MILES                                             91.90


AVERAGE TOTAL CTV HOURS                                             10.91


AVERAGE TOTAL CTV MANHOURS                                          10.91
```

CONTAINER-TRANSFER-VEHICLE REPORT

(CONTAINER-TRAIN SYSTEMS)

FIGURE VII - 5

```
CONVOY REPORT

   CONVOY NO. 01

   TRAIN NOS.   001, 002, 003, 004

   CTV NO. 009

AVERAGE TOTAL TIME                                                46.63 HOURS
   AVERAGE TOTAL TRAVEL TIME                                       7.20 HOURS
   AVERAGE TOTAL COLLECTION TIME                                  26.61 HOURS
   AVERAGE TOTAL NON-COLLECTION TIME                               2.11 HOURS
   AVERAGE TOTAL WEIGHING TIME                                     0.20 HOURS
   AVERAGE TOTAL DUMP TIME                                         3.31 HOURS
   AVERAGE TOTAL TIME TRAINS WAIT                                  5.20 HOURS
   AVERAGE TOTAL TIME CTV WAITS TO DUMP TRAINS                     1.90 HOURS
   AVERAGE TOTAL TIME CTV WAITS AT DISPOSAL SITE                   0.10 HOURS
      AVERAGE TOTAL TIME CTV WAITS AT SCALES                       0.10 HOURS
      AVERAGE TOTAL TIME CTV WAITS TO DUMP                         0.00 HOURS
   AVERAGE TOTAL PRESCHEDULED ACTIVITY TIME                        0.00 HOURS
   AVERAGE TOTAL DOWN TIME                                         0.00 HOURS

AVERAGE TOTAL DISTANCE TRAVELED                                  186.56 MILES
   AVERAGE TOTAL TRAVEL DISTANCE                                 133.25 MILES
   AVERAGE TOTAL COLLECTION DISTANCE                              29.10 MILES
   AVERAGE TOTAL NON-COLLECTION DISTANCE                          24.21 MILES
   AVERAGE TOTAL PRESCHEDULED ACTIVITY DISTANCE                    0.00 MILES

AVERAGE TOTAL NO. OF TRIPS TO DISPOSAL SITE                        8.0

AVERAGE TOTAL NO. OF TRAINS DUMPED                                24.2

AVERAGE TOTAL NO. OF FIXED CONTAINERS DUMPED                      34

AVERAGE TOTAL NO. OF RESIDENTIAL UNITS SERVED                   2763
   AVERAGE FLOOR AREA PER RESIDENTIAL UNIT SERVED               1349 SQ. FT.
   AVERAGE NO. OF PEOPLE PER RESIDENTIAL UNIT SERVED               3.96
   AVERAGE INCOME PER RESIDENTIAL UNIT SERVED                 $ 8153

AVERAGE TOTAL NO. OF CARRY OUTS                                  385

AVERAGE TOTAL AMOUNT OF SOLID WASTE COLLECTED                  78532 LBS.
   AVERAGE TOTAL AMOUNT COLLECTED FROM TRAINS                  67751 LBS.
   AVERAGE TOTAL AMOUNT COLLECTED FROM FIXED CONTAINERS        10781 LBS.

AVERAGE TOTAL EQUIPMENT MILES                                    186.56
   TRAIN MILES                                                    94.66
   CTV MILES                                                      91.90

AVERAGE TOTAL EQUIPMENT HOURS                                     46.63
   TRAIN HOURS                                                    35.72
   CTV HOURS                                                      10.91

AVERAGE TOTAL MANHOURS                                           118.07
   TRAIN MANHOURS                                                107.16
   CTV MANHOURS                                                   10.91
```

CONVOY REPORT
FIGURE VII - 6

```
SYSTEM REPORT

   CONVOY NOS.   01, 02

AVERAGE TOTAL TIME                                                 88.66 HOURS
   AVERAGE TOTAL TRAVEL TIME                                       13.95 HOURS
   AVERAGE TOTAL COLLECTION TIME                                   48.50 HOURS
   AVERAGE TOTAL NON-COLLECTION TIME                                4.10 HOURS
   AVERAGE TOTAL WEIGHING TIME                                      0.45 HOURS
   AVERAGE TOTAL DUMP TIME                                          6.90 HOURS
   AVERAGE TOTAL TIME TRAINS WAIT                                  11.76 HOURS
   AVERAGE TOTAL TIME CTV WAITS TO DUMP TRAINS                      2.85 HOURS
   AVERAGE TOTAL TIME CTV WAITS AT DISPOSAL SITE                    0.15 HOURS
      AVERAGE TOTAL TIME CTV WAITS AT SCALES                        0.15 HOURS
      AVERAGE TOTAL TIME CTV WAITS TO DUMP                          0.00 HOURS
   AVERAGE TOTAL PRESCHEDULED ACTIVITY TIME                         0.00 HOURS
   AVERAGE TOTAL DOWN TIME                                          0.00 HOURS

AVERAGE TOTAL DISTANCE TRAVELED                                   367.36 MILES
   AVERAGE TOTAL TRAVEL DISTANCE                                  268.52 MILES
   AVERAGE TOTAL COLLECTION DISTANCE                               51.70 MILES
   AVERAGE TOTAL NON-COLLECTION DISTANCE                           47.14 MILES
   AVERAGE TOTAL PRESCHEDULED ACTIVITY DISTANCE                     0.00 MILES

AVERAGE TOTAL NO. OF TRIPS TO DISPOSAL SITE                         15.0

AVERAGE TOTAL NO. OF TRAINS DUMPED                                  48.4

AVERAGE TOTAL NO. OF FIXED CONTAINERS DUMPED                          57

AVERAGE TOTAL NO. OF RESIDENTIAL UNITS SERVED                      42521
   AVERAGE FLOOR AREA PER RESIDENTIAL UNIT SERVED                   1452 SQ. FT.
   AVERAGE NO. OF PEOPLE PER RESIDENTIAL.UNIT SERVED                4.13
   AVERAGE INCOME PER RESIDENTIAL UNIT SERVED                    $  8457

AVERAGE TOTAL NO. OF CARRY OUTS                                      450

AVERAGE TOTAL AMOUNT OF SOLID WASTE COLLECTED                     135508 LBS.
   AVERAGE TOTAL AMOUNT COLLECTED FROM TRAINS                     117016 LBS.
   AVERAGE TOTAL AMOUNT COLLECTED FROM FIXED CONTAINERS            18492 LBS.

AVERAGE TOTAL EQUIPMENT MILES                                     367.36
   TRAIN MILES                                                    168.91
   CTV MILES                                                      198.45

AVERAGE TOTAL EQUIPMENT HOURS                                      88.66
   TRAIN HOURS                                                     67.95
   CTV HOURS                                                       20.71

AVERAGE TOTAL MANHOURS                                            224.56
   TRAIN MANHOURS                                                 203.85
   CTV MANHOURS                                                    20.71
```

SYSTEM REPORT
(CONTAINER-TRAIN SYSTEMS)
FIGURE VII - 7

```
COLLECTION VEHICLE REPORT

   VEHICLE NO. 001        CAPACITY    10000 LBS.           CREW SIZE   3

   HQ. NO. 1              DISPOSAL SITE NO. 2

   COLLECTION ROUTE   FROM LINK NO. 0001 TO LINK NO. 0187

AVERAGE TOTAL LENGTH OF COLLECTION DAY                              6.94 HOURS
   AVERAGE TRAVEL TIME                                              0.90 HOURS
   AVERAGE COLLECTION TIME                                          5.30 HOURS
   AVERAGE NON-COLLECTION TIME                                      0.40 HOURS
   AVERAGE WEIGHING TIME                                            0.03 HOURS
   AVERAGE DUMP TIME                                                0.31 HOURS
   AVERAGE TIME WAITING AT DISPOSAL SITE                            0.00 HOURS
      AVERAGE TIME WAITING AT SCALES                                0.00 HOURS
      AVERAGE TIME WAITING TO DUMP                                  0.00 HOURS
   AVERAGE PRESCHEDULED ACTIVITY TIME                               0.00 HOURS
   AVERAGE DOWN TIME                                                0.00 HOURS

AVERAGE TOTAL DISTANCE TRAVELED                                    31.90 MILES
   AVERAGE TRAVEL DISTANCE                                         20.45 MILES
   AVERAGE COLLECTION DISTANCE                                      6.26 MILES
   AVERAGE NON-COLLECTION DISTANCE                                  5.19 MILES
   AVERAGE PRESCHEDULED ACTIVITY DISTANCE                           0.00 MILES

AVERAGE TOTAL NO. OF TRIPS TO DISPOSAL SITE                          2.0

AVERAGE TOTAL NO. OF NON-RESIDENTIAL UNITS SERVED                    699
   AVERAGE FLOOR AREA PER RESIDENTIAL UNIT SERVED                   1235 SQ. FT.
   AVERAGE NO. OF PEOPLE PER RESIDENTIAL UNIT SERVED                4.35
   AVERAGE INCOME PER RESIDENTIAL UNIT SERVED                     $ 6876
   AVERAGE NO. OF ALLEY/STREET CONTAINERS                            175

AVERAGE TOTAL NO. OF CARRY OUTS                                        0
   AVERAGE NO. OF TYPE-ONE CARRY OUTS                                  0
   AVERAGE NO. OF TYPE-TWO CARRY OUTS                                  0
   AVERAGE NO. OF TYPE-THREE CARRY OUTS                                0

AVERAGE TOTAL AMOUNT OF SOLID WASTE COLLECTED                      16679 LBS.

AVERAGE TOTAL COLLECTION VEHICLE MILES                             31.90

AVERAGE TOTAL COLLECTION VEHICLE HOURS                              6.94

AVERAGE TOTAL MANHOURS                                             20.82
```

COLLECTION VEHICLE REPORT
(OTHER RESIDENTIAL COLLECTION SYSTEMS)

FIGURE VII - 8

```
SYSTEM REPORT

   COLLECTION VEHICLE NOS.   001, 002, 003, 004

AVERAGE TOTAL TIME                                              30.56 HOURS
   AVERAGE TOTAL TRAVEL TIME                                     3.63 HOURS
   AVERAGE TOTAL COLLECTION TIME                                23.33 HOURS
   AVERAGE TOTAL COLLECTION TIME                                 2.10 HOURS
   AVERAGE TOTAL WEIGHING TIME                                   0.15 HOURS
   AVERAGE TOTAL DUMP TIME                                       1.29 HOURS
   AVERAGE TOTAL TIME WAITING AT DISPOSAL SITE                   0.10 HOURS
      AVERAGE TOTAL TIME WAITING AT SCALES                       0.10 HOURS
      AVERAGE TOTAL TIME WAITING TO DUMP                         0.00 HOURS
   AVERAGE TOTAL PRESCHEDULED ACTIVITY TIME                      0.00 HOURS
   AVERAGE TOTAL DOWN TIME                                       0.00 HOURS

AVERAGE TOTAL DISTANCE TRAVELED                                134.42 MILES
   AVERAGE TOTAL TRAVEL DISTANCE                                81.38 MILES
   AVERAGE TOTAL COLLECTION DISTANCE                            29.10 MILES
   AVERAGE TOTAL NON-COLLECTION DISTANCE                        23.93 MILES
   AVERAGE TOTAL PRESCHEDULED ACTIVITY DISTANCE                  0.00 MILES

AVERAGE TOTAL NO. OF TRIPS TO DISPOSAL SITE                      8.0

AVERAGE TOTAL NO. OF RESIDENTIAL UNITS SERVED                   2763
   AVERAGE FLOOR AREA PER RESIDENTIAL UNIT SERVED               1349 SQ. FT.
   AVERAGE NO. OF PEOPLE PER RESIDENTIAL UNIT SERVED            3.98
   AVERAGE INCOME PER RESIDENTIAL UNIT SERVED                 $ 8154
   AVERAGE NO. OF ALLEY/STREET CONTAINERS                        691

AVERAGE TOTAL NO. OF CARRY OUTS                                  349

AVERAGE TOTAL AMOUNT OF SOLID WASTE COLLECTED                  68638 LBS.

AVERAGE TOTAL COLLECTION VEHICLE MILES                        134.42

AVERAGE TOTAL COLLECTION VEHICLE HOURS                         30.56

AVERAGE TOTAL MANHOURS                                         91.68
```

SYSTEM REPORT
(OTHER RESIDENTIAL COLLECTION SYSTEMS)

FIGURE VII - 9

```
CTV REPORT

   CTV NO. 11              CAPACITY    10000 LBS.              CREW SIZE   1

   HQ. NO. 1               DISPOSAL SITE NO. 2

   COLLECTION ROUTE   FROM COLLECTION UNIT NO. 0115 TO COLLECTION UNIT NO. 0247

AVERAGE TOTAL LENGTH OF COLLECTION DAY                          8.65 HOURS
   AVERAGE TRAVEL TIME                                          4.05 HOURS
   AVERAGE COLLECTION TIME                                      3.25 HOURS
   AVERAGE WEIGHING TIME                                        0.15 HOURS
   AVERAGE DUMP TIME                                            1.15 HOURS
   AVERAGE TIME WAITING AT DISPOSAL SITE                        0.05 HOURS
      AVERAGE TIME WAITING AT SCALES                            0.05 HOURS
      AVERAGE TIME WAITING TO DUMP                              0.00 HOURS
   AVERAGE PRESCHEDULED ACTIVITY TIME                           0.00 HOURS
   AVERAGE DOWN TIME                                            0.00 HOURS

AVERAGE TOTAL DISTANCE TRAVELED                               103.21 MILES
   AVERAGE TRAVEL DISTANCE                                    103.21 MILES
   AVERAGE PRESCHEDULED ACTIVITY DISTANCE                       0.00 MILES

AVERAGE TOTAL NO. OF TRIPS TO DISPOSAL SITE                     10.0

AVERAGE TOTAL NO. OF FIXED CONTAINERS DUMPED                     396

AVERAGE TOTAL AMOUNT OF SOLID WASTE COLLECTED                  87963 LBS.

AVERAGE TOTAL CTV MILES                                       103.21

AVERAGE TOTAL CTV HOURS                                         8.65

AVERAGE TOTAL MANHOURS                                          8.65
```

CONTAINER-TRANSFER-VEHICLE REPORT
(COMMERCIAL COLLECTION SYSTEMS)

FIGURE VII - 10

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SYSTEM REPORT

  CTV NOS.   011, 012, 013

AVERAGE TOTAL TIME                                                  26.30 HOURS
   AVERAGE TOTAL TRAVEL TIME                                        11.65 HOURS
   AVERAGE TOTAL COLLECTION TIME                                    10.12 HOURS
   AVERAGE TOTAL WEIGHING TIME                                       0.75 HOURS
   AVERAGE TOTAL DUMP TIME                                           3.33 HOURS
   AVERAGE TOTAL TIME WAITING AT DISPOSAL SITE                       0.45 HOURS
      AVERAGE TOTAL TIME WAITING AT SCALES                           0.45 HOURS
      AVERAGE TOTAL TIME WAITING TO DUMP                             0.00 HOURS
   AVERAGE TOTAL PRESCHEDULED ACTIVITY TIME                          0.00 HOURS
   AVERAGE TOTAL DOWN TIME                                           0.00 HOURS

AVERAGE TOTAL DISTANCE TRAVELED                                    340.37 MILES
   AVERAGE TOTAL TRAVEL DISTANCE                                   340.37 MILES
   AVERAGE TOTAL PRESCHEDULED ACTIVITY DISTANCE                      0.00 MILES

AVERAGE TOTAL NO. OF TRIPS TO DISPOSAL SITE                         31.0

AVERAGE TOTAL NO. OF FIXED CONTAINERS DUMPED                       914

AVERAGE TOTAL AMOUNT OF SOLID WASTE COLLECTED                   228513 LBS.

AVERAGE TOTAL CTV MILES                                            340.37

AVERAGE TOTAL CTV HOURS                                             26.30

AVERAGE TOTAL MANHOURS                                              26.30
```

SYSTEM REPORT
(COMMERCIAL CONTAINER-TRANSFER-VEHICLE SYSTEMS)

FIGURE VII - 11

```
TRUCK REPORT

   TRUCK NO. 015            CAPACITY    10000 LBS.              CREW SIZE   2

   HQ. NO. 1                DISPOSAL SITE NO. 2

   COLLECTION ROUTE   FROM COLLECTION UNIT NO. 0315 TO COLLECTION UNIT NO. 0411

AVERAGE TOTAL LENGTH OF COLLECTION DAY                                 10.64 HOURS
   AVERAGE TRAVEL TIME                                                  5.27 HOURS
   AVERAGE COLLECTION TIME                                              3.40 HOURS
   AVERAGE WEIGHING TIME                                                0.20 HOURS
   AVERAGE DUMP TIME                                                    1.35 HOURS
   AVERAGE TIME WAITING AT DISPOSAL SITE                                0.42 HOURS
      AVERAGE TIME WAITING AT SCALES                                    0.42 HOURS
      AVERAGE TIME WAITING TO DUMP                                      0.00 HOURS
   AVERAGE PRESCHEDULED ACTIVITY TIME                                   0.00 HOURS
   AVERAGE DOWN TIME                                                    0.00 HOURS

AVERAGE TOTAL DISTANCE TRAVELED                                       115.17 MILES
   AVERAGE TRAVEL DISTANCE                                            115.17 MILES
   AVERAGE TRAVEL DISTANCE                                              0.00 MILES

AVERAGE TOTAL NO. OF TRIPS TO DISPOSAL SITE                             6.0

AVERAGE TOTAL NO. OF FIXED CONTAINERS DUMPED                            197

AVERAGE TOTAL AMOUNT OF SOLID WASTE COLLECTED                         59152 LBS.

AVERAGE TOTAL TRUCK MILES                                             115.17

AVERAGE TOTAL TRUCK HOURS                                              10.64

AVERAGE TOTAL MANHOURS                                                 21.28
```

TRUCK REPORT
(COMMERCIAL PACKER-TRUCK SYSTEMS)

FIGURE VII - 12

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SYSTEM REPORT

   TRUCK NOS.   015, 016

AVERAGE TOTAL TIME                                           21.93 HOURS
   AVERAGE TOTAL TRAVEL TIME                                 11.32 HOURS
   AVERAGE TOTAL COLLECTION TIME                              7.15 HOURS
   AVERAGE TOTAL WEIGHING TIME                                0.50 HOURS
   AVERAGE TOTAL DUMP TIME                                    2.54 HOURS
   AVERAGE TOTAL TIME WAITING AT DISPOSAL SITE                0.42 HOURS
      AVERAGE TOTAL TIME WAITING AT SCALES                    0.42 HOURS
      AVERAGE TOTAL TIME WAITING TO DUMP                      0.00 HOURS
   AVERAGE TOTAL PRESCHEDULED ACTIVITY TIME                   0.00 HOURS
   AVERAGE TOTAL DOWN TIME                                    0.00 HOURS

AVERAGE TOTAL DISTANCE TRAVELED                             224.21 MILES
   AVERAGE TOTAL TRAVEL DISTANCE                            224.21 MILES
   AVERAGE TOTAL PRESCHEDULED ACTIVITY DISTANCE               0.00 MILES

AVERAGE TOTAL NO. OF TRIPS TO DISPOSAL SITE                   11.0

AVERAGE TOTAL NO. OF FIXED CONTAINERS DUMPED                   363

AVERAGE TOTAL AMOUNT OF SOLID WASTE COLLECTED                99876 LBS.

AVERAGE TOTAL TRUCK MILES                                   224.21

AVERAGE TOTAL TRUCK HOURS                                    21.93

AVERAGE TOTAL MANHOURS                                       43.86
```

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SYSTEM REPORT
(COMMERCIAL PACKER-TRUCK SYSTEMS)

FIGURE VII - 13